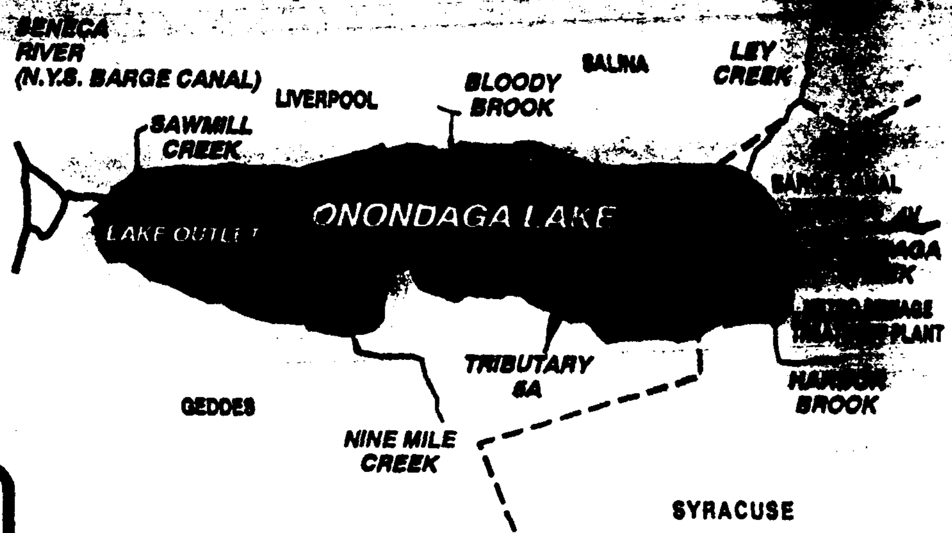
TECHNICAL REPORT

Onondaga Lake
New York

Technical Annex



US Army Corps
of Engineers
Buffalo District

March 1992

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Technical Report, Onondaga Lake, New York: Technical Annex.	5. TYPE OF REPORT & PERIOD COVERED Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer District, Buffalo 1776 Niagara Street Buffalo, N.Y. 14207-3199	10. PROGRAM ELEMENT PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE 1992
	13. NUMBER OF PAGES 500
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Onondaga Lake
Water Quality
Water Pollution

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This technical report on Onondaga Lake, New York has compiled existing data to determine which water quality and environmental enhancements are advisable. The report identifies sediment and water quality problems and needs, potential clean-up methodologies, fisheries and fish habitat improvements, and water quality improvements.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ANNEX A

Onondaga Lake
New York

Water Quality
Technical Annex

ONONDAGA LAKE, NEW YORK

TECHNICAL REPORT

Annex A
Water Quality

Technical Annex

February 1992

ONONDAGA LAKE RECONNAISSANCE REPORT
APPENDIX A

Table of Contents

	Page
1. **INTRODUCTION**	1
1.1 Objectives of This Appendix	1
1.2 Historical Water Quality	1
1.3 Pollution Abatement Efforts to Date	1
2. **CURRENT WATER QUALITY AND TRENDS**	4
2.1 General	4
2.2 Productivity and Nutrients	5
2.2.1 Phosphorus	5
2.2.2 Nitrogen	8
2.3 Oxygen Resources	9
2.4 Ionic Balance	13
2.5 Heavy Metals	15
2.6 Bacteria	19
2.7 Ammonia Toxicity	25
2.8 Transparency	31
3. **SOURCES OF POLLUTANTS**	31
3.1 Sources	31
3.1.1 Wastewater Treatment Plant	31
3.1.2 Combined Sewer Overflows	33
3.1.3 Industrial	38
3.1.4 Tributaries	40
3.1.4.1 Nine Mile Creek	40
3.1.4.2 Onondaga Creek	43
3.1.4.3 Ley Creek	44
3.1.4.4 Harbor Brook	44
3.1.4.5 East Flume	45
3.1.4.6 Tributary 5A	45
3.1.4.7 Sawmill Creek	45
3.1.4.8 Bloody Brook	45
3.1.5 Old Disposal Sites	45
3.1.6 Non Point Sources	49
3.1.7 Sediments	53
3.2 Loads	53

3.2.1 Nutrients 53

3.2.1.1 Phosphorus 53
3.2.1.2 Nitrogen 55

3.2.2 Ionic Salts 58
3.2.3 Heavy Metals 58
3.2.4 Bacteria 59

4. CURRENT STUDIES 59

4.1 United States Environmental Protection Agency (USEPA) 59
4.2 New York State Department of Environmental Conservation (NYSDEC) 59

4.2.1 General 59
4.2.2 Remedial Program Pursuant to New York State v. Allied-Signal Inc. NDNY 89 CV 815 60
4.2.3 Natural Resource Damages 60
4.2.4 Fish Sampling Program (Mercury Trend Program) 60
4.2.5 Allied Waste Beds Closure 61
4.2.6 Water Quality Model Development 61
4.2.7 Non Point Sources 61
4.2.8 Sludge Disposal 62
4.2.9 Inactive Hazardous Waste Sites 62

4.2.9.1 Allied Tar Beds 62
4.2.9.2 Allied Willis Avenue 62
4.2.9.3 LCP Plant Site 62
4.2.9.4 Clark Property 63
4.2.9.5 Quanta 63
4.2.9.6 Maestri 63
4.2.9.7 McKesson 63
4.2.9.8 Major Oil Storage Facilities Groundwater Contamination Investigation and Remediations 63
4.2.9.9 DOT Canal Maintenance Area 63

4.3 New York State Attorney General's Office 64
4.4 Onondaga County Department of Drainage and Sanitation 64

4.4.1 General 64
4.4.2 Ley Creek and Liverpool Pump Stations 64
4.4.3 Metropolitan Wastewater Treatment Plant 65

4.4.3.1 Develop Current Plant Performance Characteristics 65
4.4.3.2 Evaluate the Impact of Extraneous Flow Abatement Program 65
4.4.3.3 Evaluate Impact of Ley Creek and Liverpool Pump Station Upgrading 65
4.4.3.4 Evaluate Impacts of CSO Pollutant Reduction Alternatives 65

4.4.3.5 Evaluate Impact of Upgrading and/or Expansion of Ley Creek STP 66
4.4.3.6 Determine Performance Characteristics for Phosphorus Removal Alternatives 66
4.4.3.7 Determine Performance Characteristics for Ammonia Removal (Nitrification) Alternatives 66
4.4.3.8 Determine Performance Characteristics for Nitrogen Removal (Denitrification) Alternatives 66
4.4.3.9 Develop Effluent Discharge Alternatives 67
4.4.3.10 Develop Flows and Pollutant Loadings to Ley Creek, Onondaga Lake, and Seneca River for METRO STP Management Alternatives 67
4.4.3.11 Develop Preliminary Design Information and Cost Estimates for Selected METRO STP Management Alternatives 67

4.4.4 Combined Sewer Overflows 67

4.4.4.1 Combined Sewer Overflow Flow Monitoring 67
4.4.4.2 CSO Quality Monitoring 67
4.4.4.3 Develop SWMM Models of Existing Collection System 67
4.4.4.4 Develop Engineering Alternatives 68
4.4.4.5 Develop Loading Calculations for the Abatement Alternatives 68

4.4.5 Monitoring 68

4.5 Central New York Regional Planning and Development Board 68
4.6 Upstate Freshwater Institute 69

4.6.1 General 69
4.6.2 Phytoplankton Model 71
4.6.3 Phosphorus Model 71
4.6.4 Ammonia Nitrogen Model 71
4.6.5 Fecal Coliform Bacterial Model 72
4.6.6 Dissolved Oxygen 72
4.6.7 Transparency 72

4.7 Management Conference 72
4.8 Oswego River Citizens Advisory Committee 73
4.9 Syracuse-Onondaga County Planning Agency 74

5. **MANAGEMENT ALTERNATIVES AND COSTS** 75

5.1 METRO STP 75

5.1.1 Phosphorus Removal Alternatives 75
5.1.2 Nitrification Alternatives 76
5.1.3 Nitrogen Removal Alternatives 76
5.1.4 Effluent Discharge Alternative 77

5.2 CSO Treatment and/or Diversion 78

5.2.1 Separation of Combined Sewer System 78
5.2.2 Regionalized Collection/Treatment 80

5.2.2.1 Onondaga Creek Regional Facilities 86

5.2.2.1.1 Midland Service Area Regional Facilities 86
5.2.2.1.2 Clinton Station Area CSO Regional Facilities 86
5.2.2.1.3 Franklin Street CSO Treatment Facility 87
5.2.2.1.4 Maltbie Street CSO Treatment Facility 87
5.2.2.1.5 Newell Street CSO Demonstration Facility 88
5.2.2.1.6 Erie Boulevard CSO Treatment Facility 88

5.2.2.2 Harbor Brook Regional Facilities 88

5.2.2.2.1 Delaware Street CSO Treatment Facility 88
5.2.2.2.2 State Fair Boulevard CSO Treatment Facility 89

5.2.2.3 Ley Creek Regional CSO Treatment Facilities 89

5.2.2.3.1 Teall Avenue CSO Treatment Facility 89
5.2.2.3.2 Hiawatha Boulevard CSO Treatment Facility 90

5.2.2.4 Summary of Regional Treatment Facilities 90

5.2.3 Centralized Collection/Treatment 91

5.2.3.1 Onondaga Creek Centralized CSO Interceptor Pipeline 99
5.2.3.2 High Rate Treatment Facilities - Onondaga Creek 99
5.2.3.3 FBM Facilities - Onondaga Creek 99
5.2.3.4 In-Line Storage Tunnels - Onondaga Creek 101
5.2.3.5 Harbor Brook CSO Interceptor Pipeline 101
5.2.3.6 High Rate Treatment Facilities - Harbor Brook 101
5.2.3.7 FBM Facilities - Harbor Brook 101
5.2.3.8 In-Line Storage Tunnels - Harbor Brook 102
5.2.3.9 Ley Creek Facilities 102
5.2.3.10 Combination of Onondaga Creek and Harbor Brook 102

5.2.3.11 High Rate Treatment Facilities - Onondaga Creek and Harbor Brook 102
5.2.3.12 FBM Facilities - Onondaga Creek and Harbor Brook 102
5.2.3.13 In-Line Storage Tunnels - Onondaga Creek and Harbor Brook 103

5.2.4 Detention Reservoirs 103

5.3 Sediments 103

5.3.1 Dredging 103

5.3.1.1 Dredging Equipment 104

5.3.1.1.1 Mechanical Dredges 104
5.3.1.1.2 Hydraulic Dredges 110
5.3.1.1.3 Pneumatic Dredges 112
5.3.1.1.4 Specialty Dredges 112

5.3.1.2 Selection of Dredging Equipment 115
5.3.1.3 Cost Estimates 115

5.3.2 Disposal Sites 116

5.3.2.1 Ley Creek Confined Disposal Facility (CDF) 119
5.3.2.2 Harbor Brook Confined Disposal Facility (CDF) 119
5.3.2.3 Lakeview Point Confined Disposal Facilities (CDF) 119
5.3.2.4 Cost Estimates 131

5.3.3 Solidification/Stabilization 136

5.3.3.1 Lime-Based Pozzolan Solidification/ Stabilization 136
5.3.3.2 Mixing Considerations 136
5.3.3.3 Feasibility of Solidification Processes 137
5.3.3.4 Cost Estimates 137

5.3.4 Capping 138

5.3.4.1 Estimated Cost 141

5.4 Waste Beds 142
5.5 Mud Boils 155

5.5.1 Description of Plan 156
5.5.2 Cost Estimate 156

5.6 In-Lake Treatments 162

5.6.1 Hypolimnetic Aeration/Oxygenation 162

5.6.1.1 Mechanical Agitation 163
5.6.1.2 Air Injection Systems 163

5.6.1.2.1 Bubbler System Design 163
5.6.1.2.2 Full Air Lift Designs 166
5.6.1.2.3 Partial Air Lift Designs 166
5.6.1.2.4 Hybrid Systems 172

5.6.1.3 Pure Oxygen Injection Designs 176

5.6.1.3.1 Side-Stream Pumping 176
5.6.1.3.2 Other Pure Oxygen Designs 176
5.6.1.3.3 Goals for Oxygenating the Hypolimnion of Onondaga Lake 183
5.6.1.3.4 Hypolimnetic Oxygen Demand for Onondaga Lake 183
5.6.1.3.5 Oxygen Sag Example 195
5.6.1.3.6 Amount of Air Needed 195

5.6.1.4 Pure Oxygen Aeration System for Onondaga Lake 197

5.6.1.4.1 Equipment Description 197
5.6.1.4.2 Preliminary Cost Estimate 198
5.6.1.4.3 Variable Oxygen Cost 200

5.6.2 Chemical Treatment 201

5.6.2.1 Dosage Determination 203
5.6.2.2 Dosage Determination Method 204
5.6.2.3 Alum Application Equipment 207
5.6.2.4 1989 Alkalinity Data 214
5.6.2.5 1989 pH Data 214
5.6.2.6 Lake Distribution of Alkalinity and pH 214
5.6.2.7 Time of Alum Application 215
5.6.2.8 Onondaga Lake Alum Dosage and Total Amount Needed 215
5.6.2.9 Cost Estimate 219

5.7 Non Point Sources 220

6. **EVALUATE MEASURES** 221

6.1 Methods of Evaluation 221

6.1.1 Event Bacteria Model 227
6.1.2 Stochastic Total Phosphorus Model 227
6.1.3 Total Phosphorus Loadings and Discussion 227
6.1.4 Phosphorus Model Application 235
6.1.5 Phosphorus Loading and Trophic Status 235
6.1.6 Nitrogen Loading and Trophic Status 237

6.2 METRO Measures 237

6.2.1 Phosphorus Removal 237
6.2.2 Nitrogen Removal 239
6.2.3 Ammonia Removal 240
6.2.4 METRO Diversion and Seneca River 240

6.3 Combined Sewer Overflow Treatment Measures 241

6.3.1 Regional Collection and Treatment 241
6.3.2 Centralized Collection and Treatment Discharge to Onondaga Lake 247
6.3.3 Centralized Collection and Treatment Discharge to Seneca River 247

6.4 Dredging and Disposal 247
6.5 Capping 248
6.6 Waste Beds 248
6.7 Mud Boils 248
6.8 In-Lake Oxygenation 249
6.9 In-Lake Treatment 251
6.10 Single Goal Alternative 252
6.11 Multiple Goal Alternative 254

7. CONCLUSIONS 258

8. ADDITIONAL STUDIES 262

FIGURES

Number	Title	
1	Orthophosphate Concentration 1973-1988	6
2	Total Inorganic Phosphorus Concentration 1973-1988	7
3	Nitrite Concentration 1972-1988	10
4	Nitrate Concentration 1972-1988	11
5	Total Kjeldahl Nitrogen Concentration 1972-1988	12
6	Epilimnion Dissolved Oxygen 1973-1988	14
7	Annual Volume Averaged Chloride Concentration 1970-1988	16
8	Annual Volume Averaged Sodium Concentration 1970-1988	17
9	Annual Volume Averaged Calcium Concentration 1970-1988	18
10	Zinc Concentration 1976-1988	20
11	Lead Concentration 1976-1979, 1981-1988	21
12	Copper Concentration 1970 & 1976-1988	22
13	Chromium Concentration 1970-1988	23
14	Cadmium Concentration 1976-1988	24
15	Concentration of Fecal Coliform Bacteria 1974-1988	26
16	Fecal Strep Concentration 1974-1988	27

17	1988 Hypolimnion Ammonia Compared to NYSDEC	28
18	1988 Epilimnion Concentrations of Ammonia Compared to NYSDEC	29
19	Ammonia Concentration 1972-1988	30
20	Secchi Depth 1972-1988	32
21	Sodium and Calcium Concentration METRO 1981-1988	34
22	Chloride Concentration METRO 1981-1988	35
23	Specific Conductivity, Nine Mile Creek, and METRO Effluent 1981-1988	36
24	Sodium and Calcium Concentration Nine Mile Creek 1981-1988	41
25	Chloride Concentration Nine Mile Creek 1981-1988	42
26	Location Map of Allied Disposal Sites	47
27	Location Map of Hazardous Waste Sites	48
28	Concentration of Mercury in Two Sediment Cores	54
29	Total Phosphorus Loads	56
30	Phosphorus Loading/Trophic State Plot	57
31	Typical Combined Sewer System	79
32	Regionalized CSO Treatment Concept	81
33	Swirl Concentrator Concept	82
34	Regionalized CSO Treatment Scheme	83
35	Regionalized CSO Treatment Scheme Ley Creek	84
36	Flow Schematic - Regional Facilities	85
37	Centralized CSO Treatment Concept	93
38	Centralized CSO Treatment Scheme	94
39	Typical In-Water CSO Abatement Facility	96
40	Control System for In-Water Facility Disinfection	98
41	Sediments Containing Mercury Concentrations Greater Than or Equal to 1 ppm	105
42	Sediments Containing Mercury Concentrations Greater Than or Equal to 5 ppm	106
43	Sediments Containing Mercury Concentrations Greater Than or Equal to 10 ppm	107
44	Bucket, Cutterhead, and Dustpan Dredges	108
45	PNEUMA Pump Pneumatic Dredge	113
46	Clean-Up and Matchbox Dredges	114
47	Location of Ley Creek, Harbor Brook, and Plan 1 - CDF Alternatives	118
48	Cross Section of Lakeview Point CDF Plan 1	121
49	Cross Sections of Lakeview Point CDF Plan 1	122
50	Location of Lakeview Point CDF Plan 2	123
51	Cross Section of Lakeview Point CDF Plan 2	124
52	Cross Section of Lakeview Point CDF Plan 2	125
53	Location of Lakeview Point CDF Plan 3 & 4	127
54	Cross Section of Lakeview Point CDF Plan 3	128
55	Cross Section of Lakeview Point CDF Plan 3	129
56	Cross Section of Lakeview Point CDF Plan 3	130
57	Cross Section of Lakeview Point CDF Plan 4	132
58	Cross Section of Lakeview Point CDF Plan 4	133
59	Schematic of Capping Operations	140
60	Diversion Plan	157
61	Typical Diversion Channel Section	158

62	Typical Enlarged Channel Section	159
63	Settling Basin Plan View	160
64	Settling Basin Profile	161
65	Mechanical Aeration of Hypolimnion	164
66	Air-Oxygen Bubbler System	165
67	Full Air Lift Hypolimnetic Aerator	167
68	Full Air Lift Hypolimnetic Aerator	168
69	Full Air Lift Hypolimnetic Aerator	169
70	Full Air Lift Hypolimnetic Aerator	170
71	Full Air Lift Hypolimnetic Aerator	171
72	Partial Air Lift Hypolimnetic Aerator	173
73	Partial Air Lift Hypolimnetic Aerator	174
74	Standpipe Hypolimnetic Aerator	175
75	Downflow Air Injection System	177
76	Side Stream Pumping Hypolimnetic Oxygenation System	178
77	Hypolimnetic Oxygenation System	179
78	Isteri Oxygen Injection System	181
79	Example of Oxygen Depletion Rates Data	185
80	Volume Weighted Mean Concentration of DO in Hypolimnion - Onondaga Lake	186
81	Bathymetric Map of Onondaga Lake	187
82	Variation of Cumulative Lake Volume with Depth	188
83	Variation of Lake Plan Area with Depth	189
84	Dissolved Oxygen in Epilimnion and Hypolimnion	191
85	Onondaga Lake Areal Hypolimnetic Oxygen Deficit	192
86	Hypolimnion Dissolved Oxygen Depletion Rate	193
87	Hypolimnion Dissolved Oxygen vs Stratification	196
88	Onondaga Lake Oxygenation System	199
89	Aluminum Dose as a Function of pH and Alkalinity	206
90	Relationship of Baume and Percent Al_2O_3	208
91	Temperature Correction	209
92	Pounds of Alum per Gallon	210
93	Schematic of Lake Alum Application	211
94	Alum Application at Irondequoit Bay	212
95	Alum Application Equipment	213
96	1989 Alkalinity Data for Onondaga Lake	216
97	1989 pH Data for Onondaga Lake	217
98	Lake Productivity and Recovery	226
99	Phosphorus Budget	229
100	Onondaga Creek TP Load - Flow Relationship	231
101	Phosphorus Loading - Trophic State Evaluation	236
102	Nitrogen Load - Productivity Evaluation	238
103	Fecal Coliform Monitoring Stations	242

Tables

Number	Title	Page
1	Onondaga County Drainage Area Land Use	2
2	Volume-Average Concentrations for Nitrogen for 1986, 1987, 1988, and 1989 in the Epilimnion and Hypolimnion	9

3	Dissolved Oxygen	13
4	Comparison of Ionic Salts in the Hypolimnion and Epilimnion for 1981, 1986, 1987, 1988, and 1989	15
5	Significant Industrial Dischargers	39
6	1988 Influent Discharge Survey Mass Loading Percent Contributions	43
7	Column Settling Test "Mud Boil" Area	52
8	Hydrometer Analysis of Sediment From "Mud Boil" Area	53
9	Comparison of Total Phosphorus Loads	55
10	Sum of the Average Mass Loading Rates of Nitrogen for 1988 and 1989	58
11	Sum of the Average Mass Loading Rates for 1984, 1988, and 1989 for Calcium, Sodium, and Chloride	58
12	Summary of Current Research Efforts on Onondaga Lake	70
13	Projected Maximum Monthly Average Effluent Concentration for Denitrification Measures	77
14	Summary of Major Design Parameters for Regional Treatment Facilities	91
15	Centralized Facility-Pipeline Summary	100
16	Summary of Dredged Operating Characteristics	109
17	Specifications for Typical Cutterhead Dredges	111
18	Cost Estimates for Dredging Contaminated Sediments	117
19	Cost Estimates for Construction of Confined Disposal Facilities	134
20	Cost Estimates for Solidification/Stabilization	138
21	Summary of Cost Estimates for Capping Measures	142
22	Cost Estimates for Capping Sediments Contaminated with 1 ppm Hg (0.5 foot of Sand)	143
23	Cost Estimates for Capping Sediments Contaminated with 1 ppm Hg (1.0 foot of Sand)	144
24	Cost Estimates for Capping Sediments Contaminated with 1 ppm Hg (2.0 feet of Sand)	145
25	Cost Estimates for Capping Sediments Contaminated with 1 ppm Hg (3.0 feet of Sand)	146
26	Cost Estimates for Capping Sediments Contaminated with 5 ppm Hg (0.5 foot of Sand)	147
27	Cost Estimates for Capping Sediments Contaminated with 5 ppm Hg (1.0 foot of Sand)	148
28	Cost Estimates for Capping Sediments Contaminated with 5 ppm Hg (2.0 feet of Sand)	149
29	Cost Estimates for Capping Sediments Contaminated with 5 ppm Hg (3.0 feet of Sand)	150
30	Cost Estimates for Capping Sediments Contaminated with 10 ppm Hg (0.5 foot of Sand)	151
31	Cost Estimates for Capping Sediments Contaminated with 10 ppm Hg (1.0 foot of Sand)	152
32	Cost Estimates for Capping Sediments Contaminated with 10 ppm Hg (2.0 feet of Sand)	153
33	Cost Estimates for Capping Sediments Contaminated with 10 ppm Hg (3.0 feet of Sand)	154
34	Cost Estimate for Mud Boil Sediment Remediation	162
35	Oxygen Transfer Efficiencies for Nine Hypolimnetic Aeration/Oxygenation Systems	182

36	Onondaga Lake Hypographic Data	184
37	UFI Hypolimnetic Oxygen Depletion Rates	190
38	Hypolimnetic Oxygen Depletion Rates From Selected Eutrophic Lakes and Reservoirs	194
39	Preliminary Capital Cost and Annual Cost at Each Site	200
40	Site Monthly Oxygen Cost Per Various Oxygenation Rates	201
41	Lake Distribution of Alkalinity and pH	214
42	Alum Chemical Treatment Cost	219
43	Evaluation of Lake Rehabilitation Measures on Onondaga Lake and the Seneca River	222
44	Comparison of Present Conditions with State Water Quality Standards	224
45	Onondaga Lake Restoration Goals	225
46	External Total Phosphorus Loads to Onondaga Lake Based on 16 June-22 August 1987	228
47	Phosphorus Loadings to Onondaga Lake	230
48	External Total Phosphorus Loads to Onondaga Creek	232
49	Comparison of External Total Phosphorus	233
50	Comparative Statistics for Onondaga Creek Phosphorus Databases	234
50	Effects of METRO Phosphorus Removal on Lake Concentrations	239
51	June Storm Modeling Results	243
52	July Storm Modeling Results	244
53	Onondaga Lake Total Phosphorus Concentration with CSO Load Reduction	246
54	Summary Table of Lake Rehabilitation Measures Selected Parameters, Goals Addressed and Cost Estimates	253
55	Single Goal Alternatives	255
56	Multiple Goal Alternatives	256
58	Summary of Problems, Causes and Consequences	258

1. INTRODUCTION

1.1 Objectives of this Appendix

There are four main objectives of this Water Quality Technical Annex of the Onondaga Lake Technical Report. They are as follows: (1) to summarize the current water quality of Onondaga Lake including the pollutant sources and their loadings to the lake; (2) to summarize the existing activities and agencies involved in the study of Onondaga Lake; (3) to develop pollution abatement and in-lake remediation alternatives; and (4) to evaluate the effectiveness of these alternatives on lake water quality. In addition, the need for additional studies is also presented.

It should be noted that the material presented herein is a summary of material existing during its writing. Some of the material has not been peer reviewed or reviewed by regulatory agencies having authority to do so. Its publishing here does not reflect approval or disapproval by those agencies.

1.2 Historical Water Quality

Onondaga Lake is an urban lake that is surrounded by commercial, industrial, and residential land use. However, 80 percent of the land immediately surrounding the lake is in public ownership, primarily park lands owned and maintained by Onondaga County. The history of the development around the lake, as well as the physical and chemical changes in the water and sediments, have been well documented over the years (Hennigan, 1989; Moffa, 1987; Effler, et al 1981; Onondaga County, 1971; Stearns and Wheler, 1979, 1980, 1981, 1987, 1988, 1989, 1990). Table 1 shows the drainage area of land use for Onondaga County.

The lake is hypereutrophic (Effer et al., 1981) and polluted (Stewart, 1979). Oxygen is depleted rapidly from the hypolimnion; the entire hypolimnion is annually anoxic by late June (Effler et al, 1986). Ionic waste (mostly chloride, sodium, and calcium) was discharged to the lake by an adjoining alkali manufacturer from the 1880s up until its closure in February 1986. The loading was approximately 2.5 x 10^6 kg/d over the last 15 years of the facility's operation. The ionic waste entered the lake via Ninemile Creek for more than 35 years, until mid-May of 1981. The loading emanated from discharges from settling ponds located several km upstream from the mouth of Ninemile Creek; and possibly from ground water releases from large waste beds containing sludge produced by the facility. Subsequently, a substantial portion of the ionic waste entered the lake via the Metropolitan Sewage Treatment Plant (METRO) discharge (the waste was used to precipitate phosphorus at METRO), until the closure of the alkali facility. The salinity of the lake was found to be generally consistent with surface water inputs to the lake; 85 percent of the salinity of the lake was attributable to inputs from the alkali manufacturer (Effler and Driscoll, 1986). The alkali plant used water from a deep layer of the lake (depth of approximately 11m) for process cooling. Heated water was returned to the epilimnion via a shoreline discharge until 1978; subsequently it was discharged through a submerged diffuser. The impact of the thermal discharge on the stratification regime of the lake was minor compared to the impact of input of ionic waste (Owens and Effler, 1985).

Table 1 Onondaga County Drainage Area

LAND USE	(Percent)
Open Space	52.2
Agriculture	25.9
Medium Density Residential	5.8
Transportation	4.6
Industrial	3.6
Water	3.1
Recreation	2.3
Institutional	1.0
Commercial	0.6
High Density Residential	0.5
Low Density Residential	0.4
TOTAL	100.0

(From Moffa, Deguida, Geldof, and Ott, 1990)

Data collected on Onondaga Lake show the presence of two major periods of circulation for each year representing the vernal and autumnal circulation. For this reason Onondaga Lake has been classified as being dimictic (Hutchinson, 1957).

The lake exhibits a rapid increase in temperature at most levels following the ice breakup in the spring. This is followed by a continued increase in temperature in the upper waters while the lower waters show little change in temperature.

After achieving the summer maximum temperature and the resulting density stratification, there is a cooling of the surface waters with the subsequent loss in stratification. In the winter, the entire lake waters cool to a temperature below 4 degrees C where an inverse stratification is initiated. This inverse stratification holds through the winter with the cycle repeated following the loss of ice in the spring.

The first major impact on the water quality of the lake began in 1793 with the commercial production of salt along the lakeshore. The peak of the salt production occurred in 1862. In the late 1800's, the Solvay Process Company began the soda ash production. The industrial revolution also brought the steel, machinery, and pottery industries to Onondaga Lake. With the increase in industry, came an increase in population. Sewers were built in the city and untreated sewage was discharged directly into Onondaga Creek and Harbor Brook.

By 1920 the recreational and commercial use of the lake had declined significantly due to deteriorating water quality caused by the continued discharge of Solvay Process waste as well as the untreated sewage. In spite of the efforts made to treat the sewage, the water quality continued to deteriorate and in 1940 the lake could no longer be used for swimming (Hennigan, 1989). By 1950, the lake was no longer used for fishing. The prime use of the lake was for sewage and industrial waste disposal. From the 1950's to the 1970's, some efforts were made to abate the pollution problems, and are described in the next section. It was not until 1975 that an Environmental Action Plan was developed and implemented by the County of Onondaga. While some of the industries were improving their treatment processes, others were creating new problems for the lake. Crucible Steel Company constructed a new wastewater treatment plant and recycling plant in 1975. Allied closed their

benzene operation in 1977. However, Linden Chemicals and Plastics (LCP) facilities continued to discharge mercury into the lake sometime after 1976 when they bought the mercury production from Allied. In 1979 the Metropolitan Syracuse Sewage Treatment Plant (METRO) expanded to secondary/tertiary treatment. The sludge was sent to Allied wastebeds. Allied wastebed overflow was directed to the METRO treatment plant to aid in precipitation of phosphorus. Dramatic caking and solids discharge problems occurred right up until Allied went out of business. METRO then switched to an iron precipitant and went truly tertiary at that point.

A water quality lake monitoring program was initiated in 1971 by Onondaga County and is summarized in their annual report. Various data have been collected every 2 weeks each year during the spring, summer, and fall as specified in the county's monitoring program since the initial baseline study of 1971.

The 1980's was a time of continued monitoring and analysis of the problems. In addition to the county's continuous record of data, the Upstate Freshwater Institute has also been collecting and analyzing data since 1981. This work resulted in a better understanding of the lake. Additional efforts to improve water quality were made by various industries and governments. The algal blooms have decreased, fisheries have improved, and clarity has improved. (Stearns and Wheler, 1990) The overall use of the lake for recreational and aesthetic purposes has increased significantly, however, the lake still remained closed to swimming and fish caught in the lake my not be eaten. Although certain aspects of pollution have shown improvement, there remains a number of current problems which are discussed below in the section entitled CURRENT WATER QUALITY AND TRENDS.

1.3 Pollution Abatement Efforts to Date

Pollution abatement efforts for Onondaga Creek began as early as 1907 when the State Legislature created the Syracuse Intercepting Sewer Board. The State empowered the Board to construct sewers to intercept the sewage going into Onondaga Creek and Harbor Brook and discharge it directly to Onondaga Lake.

The first sewage treatment plant was completed in 1925 and was constructed at the southern end of the lake. The plant provided solids settling and disinfection of the sewage. This level of treatment was provided until 1960 except during a 3-year period between 1950 and 1953 when untreated sewage was discharged into the outfall sewer. Sedimentation tanks were added in 1960, which resulted in doubling the solids removed. Another major treatment plant, built in 1940, was located at Ley Creek. This plant was the first in New York State to use the activated sludge treatment process. The Ley Creek Treatment Plant stopped discharging in 1970 and was replaced by a pumping station that conveyed the treated and untreated wastewater to the METRO plant (Moffa, 1987). For a decade or more the Ley Creek plant was operated on a partial wastewater flow bases to reduce organic loadings to METRO as much as possible.

In 1979, secondary facilities were made operational at METRO. In 1981 tertiary facilities were put into operation at METRO resulting in major reductions in phosphorus loading. The lake phosphorus levels are still high enough to support excessive algae growth.

A master plan was developed by Onondaga County for Onondaga Lake in 1966. The plan included (1) a baseline study of the lake, (2) an evaluation of tertiary or advanced treatment at the METRO plant, (3) a survey of industrial discharges that were going into the sewer system, and (4) an evaluation of the

combined sewer outfall system. The Clean Water Act of 1972 was the mechanism that enabled programs from the master plan of 1966 to become implemented (Moffa, 1987).

A combined sewer overflow study conducted in 1968 determined that the most cost-effective method of abatement would be to parallel the two existing interceptors with overflow conduits. Due to the high cost of this alternative, the county joined the Environmental Protection Agency in undertaking research and demonstration projects, but never implemented a project to address the CSO's. More recently the county has investigated a cost-effective Swedish innovation as well as a host of other corrective actions to solve the CSO problem (Moffa, 1987). These corrective measures include treating and/or diverting the CSO's, swirl concentrator treatment at central locations with interceptors running up Harbor Brook and Onondaga Creek and discharging to either the lake or the Seneca River, and swirl concentrators located at several points discharging to their respective streams. The NYSDEC has put the county under Court Order to study these CSO abatement alternatives which will be evaluated with a mathematical model of the lake.

A testing program in operation since the mid 1980's resulted in combining the waste bed overflow from Allied with the discharge from METRO's secondary or advanced facilities to comprise a chemical or tertiary treatment step. This operation was discontinued when Allied shut down in 1986. The County installed temporary chemical storage and feed equipment and replaced the use of Allied's waste lime with purchased chemicals to precipitate phosphorus. Using combinations of ferrous sulfate, ferric chloride, and/or alum the annual average effluent phosphorus concentration from METRO for 1989 and 1990 has been 0.6 mg/l and 0.5 mg/l, respectively. This represents a 50 percent reduction from the current SPDES permit limit of 1.0 mg/l.

The most notable industrial abatement was the construction of the Crucible Steel Wastewater Treatment Plant in 1974, which led to significant reductions of heavy metals in the lake.

2. CURRENT WATER QUALITY AND TRENDS

2.1 General

Onondaga Lake has water quality problems that have generated numerous studies by local, State, and Federal government agencies to identify and recommend solutions. The discharges of municipal effluents and industrial wastes over the past century have resulted in the lake becoming polluted and hypereutrophic. The transparency is generally poor (often less than 4 feet), with occasional high fecal coliform bacteria thus prohibiting swimming (Auer, 1989; Auer and Nichaus, 1989; Effler, 1988; Heidtke, 1989). The fecal coliform DOH standards are frequently violated following high runoff events primarily as a result of combined sewer overflows (Bloom and Effler, 1990; Effler, Hassett, Auer and Johnson, 1987). The fishery is impacted by mercury contamination of fish flesh, (Sloan et al, 1987) inadequate dissolved oxygen and the destruction of fish habitat (Brooks and Effler, 1989). Also affecting the fishery are the high concentrations of ammonia and nitrate (Effler, Brooks, Auer and Doerr, 1990) and the high chloride levels. The problem with oxygen depletion is so severe in the lake that adequate concentrations that can support fish life are often limited to the upper 20 percent (4-5 meters) of the water column in the summer. The entire bottom of the lake violates the NYS standards during this period. During the fall mixing period, the New York State standard for dissolved oxygen (4 mg/l) is violated throughout the water column because the

oxygen-demanding reduced chemical species which accumulate in the bottom waters during the summer mix with the upper layer and absorb all the oxygen (Effler, Hassett, Auer and Johnson, 1987; Effler, Perkins and Brooks, 1987). The transparency is low in the lake primarily because of high concentrations of phytoplankton and secondary by elevated levels of calcium carbonate and clays. The high phytoplankton concentration occurs as a result of high nutrient loadings, particularly phosphorus. Sources of phosphorus include the Metropolitan Sewage Treatment Plant, combined sewer overflows, internal recycling from bottom sediments, and non-point sources (Auer and Johnson, 1989: Devan and Effler, 1984; Effler, 1987; Effler et al 1985; Effler and Owens, 1987; Heidtke, 1989). Calcium carbonate production in the lake is enhanced by elevated calcium concentrations due to the direct discharge of landfill leachate and seepage of ionic waste from the adjoining waste bed of an alkali manufacturer even though they stopped the active discharge when they went out of business in 1986 (Effler, 1986; Effler, Schimel and Millero, 1986; Effler, Doer, Brooks and Rowell, 1985; Sonzogni, Richardson and Monteith, 1983). High concentrations of clay and other inorganic material are transported by the tributaries, particularly Onondaga Creek (Effler, Johnson, Jiao, and Perkins, 1989). The severe depletion of oxygen results from the hypereutrophic conditions of the lake and may be subject to remediation through phosphorus management efforts.

2.2 Productivity and Nutrients

The primary nutrients of concern in Onondaga Lake are phosphorus and nitrogen. Management efforts have been, and must continue to be, directed at trying to make phosphorus the limiting nutrient to algae. Efforts to control ammonia must be concerned with the phosphorus to nitrogen ratio to prevent conditions that would be favorable to nuisance blue-green algae growth.

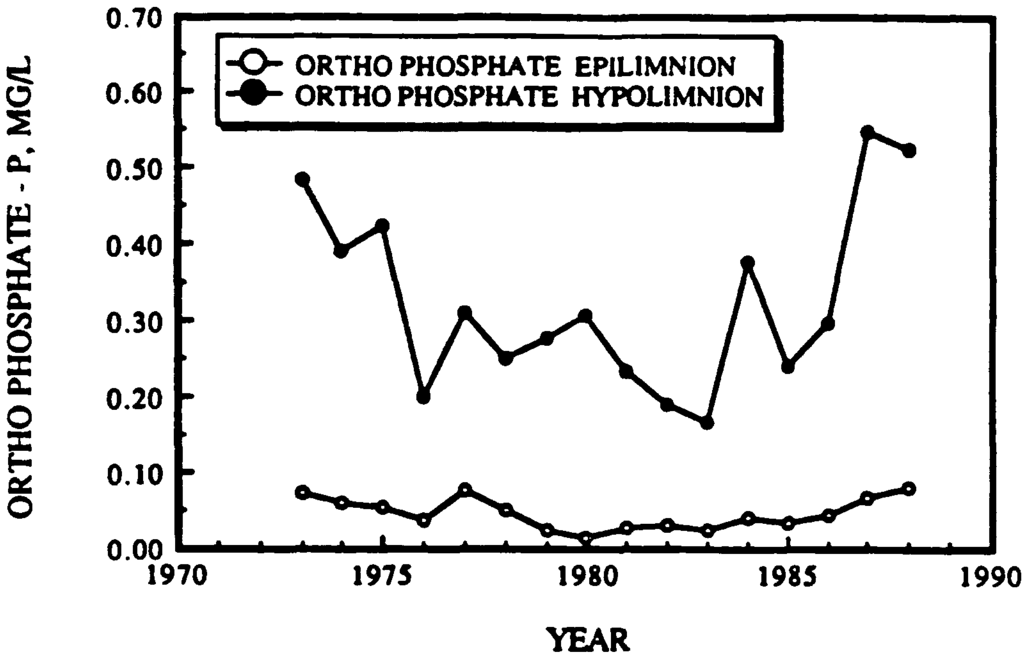
2.2.1 Phosphorus

Phosphorus has been identified as the nutrient controlling phytoplankton growth in many lakes including Onondaga Lake (Auer and Johnson, 1989). The loading of phosphorus to the lake has been reduced by more than ten-fold from 1970 through 1981. The major contributing management actions included a ban on high phosphorus detergents and the addition of secondary and tertiary processes at the sewage treatment plant.

Extensive monitoring of the phosphorus loading has been performed over the years to identify the processes and the sources (Canale and Effler, 1989; Devan and Effler, 1984; Effler et al 1986; Effler and Owens, 1987; Heidtke, 1989; Wodka et al, 1985; Onondaga County 1985, 1986, 1987, 1988, 1989). Selected components of the data base were used by Upstate Freshwater Institute (UFI) to develop a computer model for use in the evaluation of remediation scenarios.

Currently the phosphorus inputs to the lake are sufficient to support the high levels of algal production in evidence. The degraded character of the lake can largely be attributed to the high algal productivity. As a result, the transparency is low and the oxygen levels are depleted in the hypolimnetic waters.

The Onondaga County Department of Drainage and Sanitation monitoring program (Stearns and Wheler, 1990) has made the following assessment of phosphorus based on the most recent data collected. Concentrations of the phosphorus species (orthophosphate, total inorganic phosphorus, and soluble total inorganic phosphorus) are higher in the hypolimnion. Figure 1 shows the



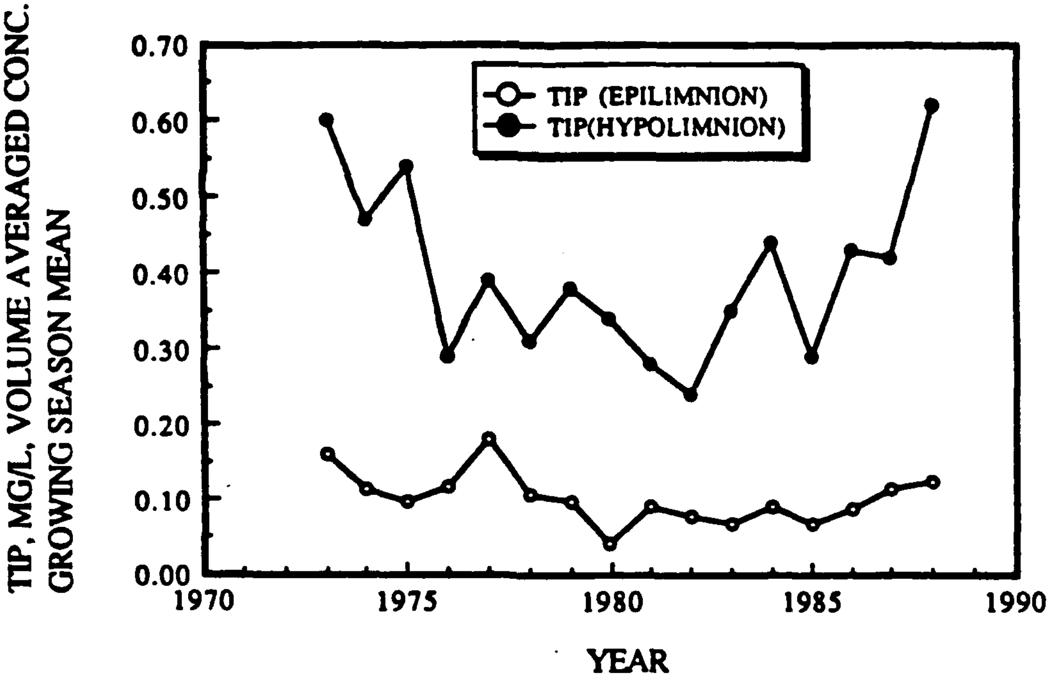
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ORTHOPHOSPHATE CONCENTRATION 1973-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 1



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TOTAL INORGANIC PHOSPHORUS CONCENTATION 1973-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 2

results for orthophosphate and Figure 2 shows the results for total inorganic phosphorus for the period 1973-1989.

2.2.2 Nitrogen

Nitrogen occurs in various forms in the aqueous environment and the underlying sediments of Onondaga Lake. A number of biogeochemical processes are largely responsible for the continuous exchanges between these forms of nitrogen. Factors that influence this cycle include the trophic state of the lake, oxygen concentrations, water chemistry, and inputs of nitrogen from the watershed and the atmosphere. Water quality is significantly affected by the concentration of the various forms of nitrogen and the various processes that regulate the transformations (Brooks, and Effler, 1989; Auer, and Brooks, 1988).

A detailed analysis of the temporal and vertical distribution of nitrate, nitrite, total ammonia, and free ammonia was performed by Brooks and Effler (1989). The data presented here is a result of that study and trends of Onondaga Lake.

The total inorganic nitrogen for the lake is the sum of ammonia + NO_2^- + NO_3^-. The study showed that the relative concentration of organic nitrogen to the total nitrogen (organic and inorganic) concentration was small. The total nitrogen content remained relatively uniform for the study period indicating that inputs and recycling of nitrogen were compensating for losses to the sediments. Of the various nitrogen species, ammonia was the largest component contributing an average of 80 percent. Nitrate was an average of 13 percent and nitrite contributed approximately 7 percent of the total.

The study concluded that the distribution of nitrogen was typical of eutrophic lakes with the exception of the following anomalies. High concentrations of NO_2^- occur in the epilimnion. Concentrations of ammonia and NO_3^- remained extremely high in the epilimnion in the productive summer months. The concentration of ammonia is very high in the hypolimnion.

In addition, the Brooks and Effler 1989 study reported evidence for operation of certain processes related to nitrogen cycling including denitrification and ammonification with less importance attributed to plant assimilation and nitrification. The sediments in the lake bottom contributed significant quantities of ammonia to the hypolimnion. EPA's national chronic standards for free ammonia concentrations were exceeded from spring to fall turnover in 1988. The levels in the upper water exceed the standards for acute toxicity on occasion and are aggravated by the high level of primary productivity.

The Onondaga County Department of Drainage and Sanitation has been reporting the yearly volume-averaged concentrations for nitrogen in the hypolimnion and the epilimnion based on their monitoring program. Results from 1986-1989 are shown in Table 2 below (Stearns and Wheler, 1989):

Table 2 Volume-Averaged and Concentrations for Nitrogen for 1986, 1987, 1988, and 1989 in the Epilimnion and Hypolimnion

Epilimnion

	1986	1987	1988	1989
NH_3^-N	1.9 mg/l	2.2 mg/l	2.8 mg/l	1.9 mg/l
NO_3^-N	.860 mg/l	.930 mg/l	.993 mg/l	1.5 mg/l
NO_2^-N	.164 mg/l	.285 mg/l	.246 mg/l	.181 mg/l

Hypolimnion

	1986	1987	1988	1989
NH_3^-N	4.6 mg/l	4.4 mg/l	4.3 mg/l	3.6 mg/l
NO_3^-N	.316 mg/l	.354 mg/l	.552 mg/l	.853 mg/l
NO_2^-N	.07 mg/l	.120 mg/l	.146 mg/l	.073 mg/l

Volume-averaged concentrations are presented in the County's annual monitoring reports. Data are reduced to a mean upper water (epilimnetic) concentration and a mean lower water (hypolimnetic) concentration through a calculation procedure that weights each water stratum by its contribution to total lake volume.

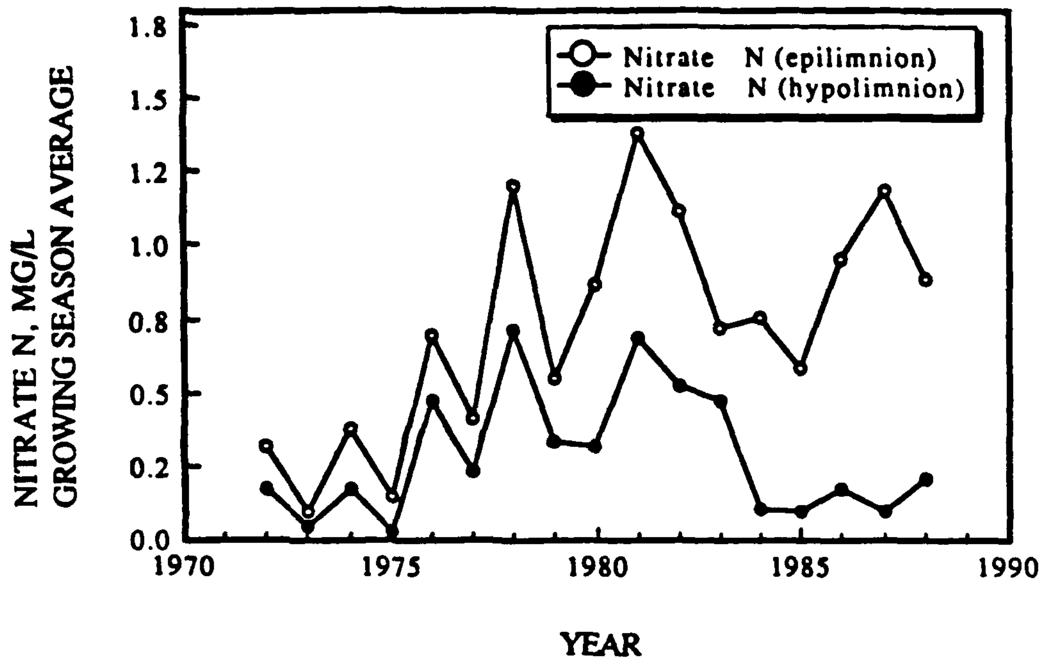
Figures 3 through 5 show the trends of nitrate and nitrite for the growing season average for the period of record.

2.3 Oxygen Resources

Oxygen depletion in the hypolimnion occurs through the summer stratification period in Onondaga Lake when the demand for oxygen exceeds the limited sources. In general, oxygen sources include photosynthesis and vertical exchange from enriched layers. Photosynthetic inputs to the hypolimnion are not present in lakes where the transparency is low. Oxygen is consumed by respiration of settling phytoplankton, oxidation of settling detritus, and through the demand at the sediment-water interface (sediment oxygen demand (SOD)) (Effler et al, 1986).

In previous studies, Onondaga Lake was classified as hypereutrophic (Effler et al, 1981; Effler et al, 1986) because (1) very high standing crops of phytoplankton; (2) water transparency was low (less than 1% of incident light penetrates to a depth of 5m); (3) a dominance of chlorococcalean green algae, and; (4) a high concentration of algal macronutrients (Effler et al, 1986). The lake is still currently described as eutrophic or hypereutrophic. Oxygen depletion in the hypolimnion is severe throughout much of the year with all but the upper 4 or 5 meters violating the NYS standard of 4 mg/l. During the fall period of complete mixing, very low concentrations of dissolved oxygen are evidenced throughout the entire water column. The New York State minimum standard of 4 mg/l was violated in the epilimnion in at least 10 years of the 1973-1986 interval (Effler et al, 1986).

The Onondaga County Department of Drainage and Sanitation monitoring program has collected dissolved oxygen data for many years. The last 4 years of annual volume-averaged concentrations for the epilimnion and hypolimnion are shown on Table 3 below (Stearns and Wheler, 1989).



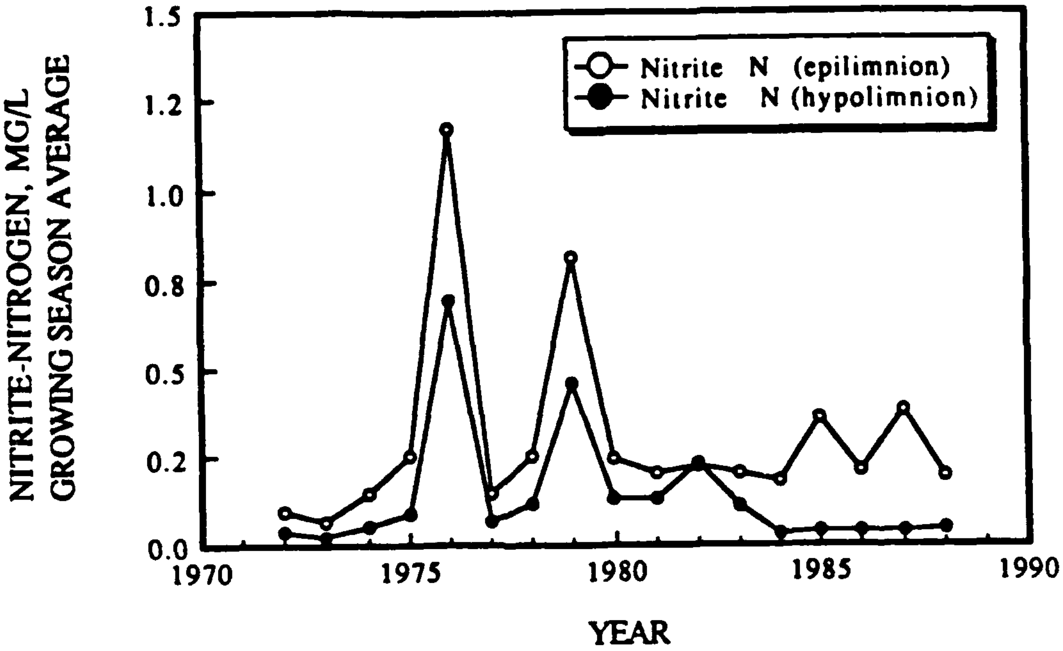
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

NITRATE CONCENTRATION 1972-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 3



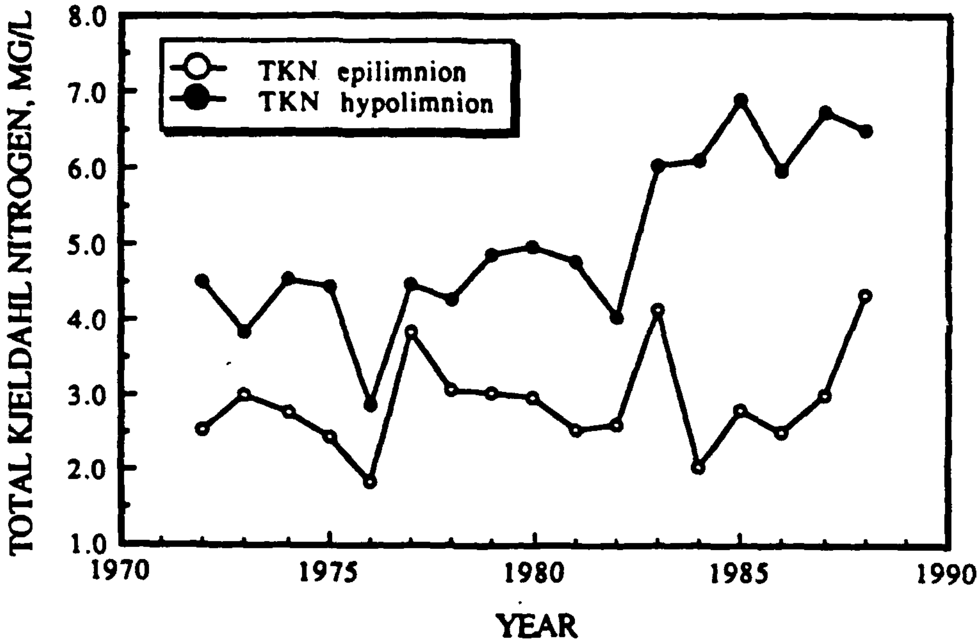
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

NITRITE CONCENTRATION 1972-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 4



From: Stearns and Whele-, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TOTAL KJELDAHL NITROGEN CONCENTRATION 1972-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 5

Table 3 Dissolved Oxygen

	1986	1987	1988	1989
Epilimnion	8.5 mg/l	8.2 mg/l	8.1 mg/l	7.5 mg/l
Hypolimnion	2.6 mg/l	3.3 mg/l	3.7 mg/l	3.6 mg/l

Figure 6 shows the mean growing season volume averaged epilimnetic dissolved oxygen for the period of record. It must be noted that these volume-averaged values are presented for annual comparisons and could tend to mask the true yearly oxygen picture for the lake, especially for the hypolimnion.

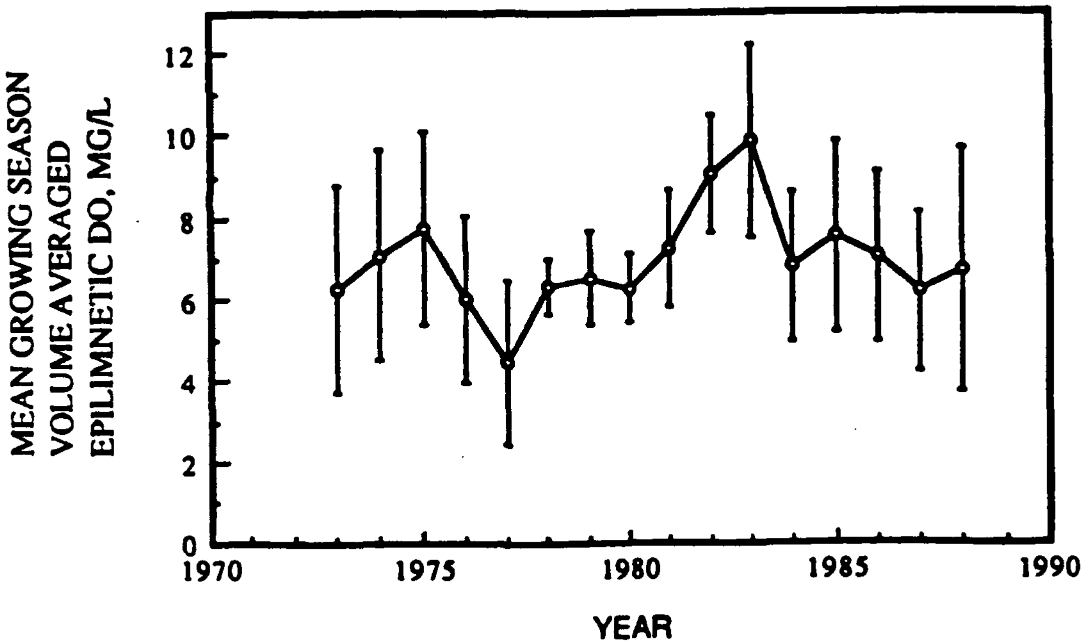
2.4 Ionic Balance

The chlor-alkali plant on Onondaga Lake has significantly impacted the water quality as well as the lake and river processes. Since the 1880's, the facility discharged ionic waste into the lake and used it as a source of cooling water. The wastewaters produced from this Solvay Process contain high concentrations of Cl, Na, and Ca. Pretreatment of the waste was performed by settling in lagoons known as wastebeds. Prior to 1981, the ionic waste entered the lake by Nine Mile Creek and earlier by direct discharge. From 1981 through 1983, a portion of the ionic waste was diverted to METRO for the removal of phosphorus in the tertiary treatment. By 1983, all of the ionic supernatant waste was diverted to METRO, however, the leachate was not included. The materials settling in the lagoons were deposited in waste beds adjacent to the lake. These waste beds continue to be a source of ionic waste through surface water and groundwater runoff (Effler, 1987), since highly contaminated groundwater recharges Nine Mile Creek in this area.

The ionic enrichment to the lake has significantly affected the physical and biological characteristics of the lake. The zooplankton commonly found are known to be tolerant of saline conditions. Two marine species of algae have been identified (Effler, 1987).

Stratification, which is a fundamental characteristic in regulating lake metabolism has been affected by ionic waste. Studies have shown that the lake was chemically, as well as thermally stratified until closure of the plant (Effler, 1987). The chemical stratification was caused by high ionic discharges into the lake and further enhanced by the denser ionic waste plunging to the lower layers of the lake during periods of low vertical density gradients. This process caused interrupted and abbreviated periods of turnover, thereby extending the period of stratification. This extended period exacerbated the oxygen depletion of the entire water column during turnover due to the greater mass of pollutants collected during that period than would normally have been collected.

Another impact that the ionic waste has had on Onondaga Lake is the change in the hydrodynamics of the outlet as well as within the Seneca River. A bi-directional flow regime sometimes occurs in the outlet as a result of the density differences. Other times it is due to other factors.



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

EPILIMNION DISSOLVED OXYGEN 1973-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 6

One particular component of the ionic waste, calcium, has been responsible for the over-saturation, precipitation, and deposition of $CaCO_3$ (primarily in the form of calcite). The calcite has been and continues to be formed from the Ca^{++} discharged by the alkali manufacturer. Studies have shown that it contributes to the turbidity because it is a dominant component of the inorganic particles in suspension (Yin and Johnson 1984; Effler, 1986, and Johnson, 1989).

Sediment traps have been used to collect data on the type of material that settles out of the water column (Effler, 1987). Results show that calcite is precipitated out. It also appears that calcium affects the rate of deposition of the phosphorus and phytoplankton. The nearshore sediments have been altered by the precipitation of calcite. Certain areas of the lake are covered with oncolites (algal calcite concretions). The concentration of calcium in the water column has also raised the rate of phosphorus deposition (Effler, 1987).

The Onondaga County Department of Drainage and Sanitation monitoring program has been collecting data for chloride, sodium, and calcium concentrations. The comparison of data is shown below in Table 4:

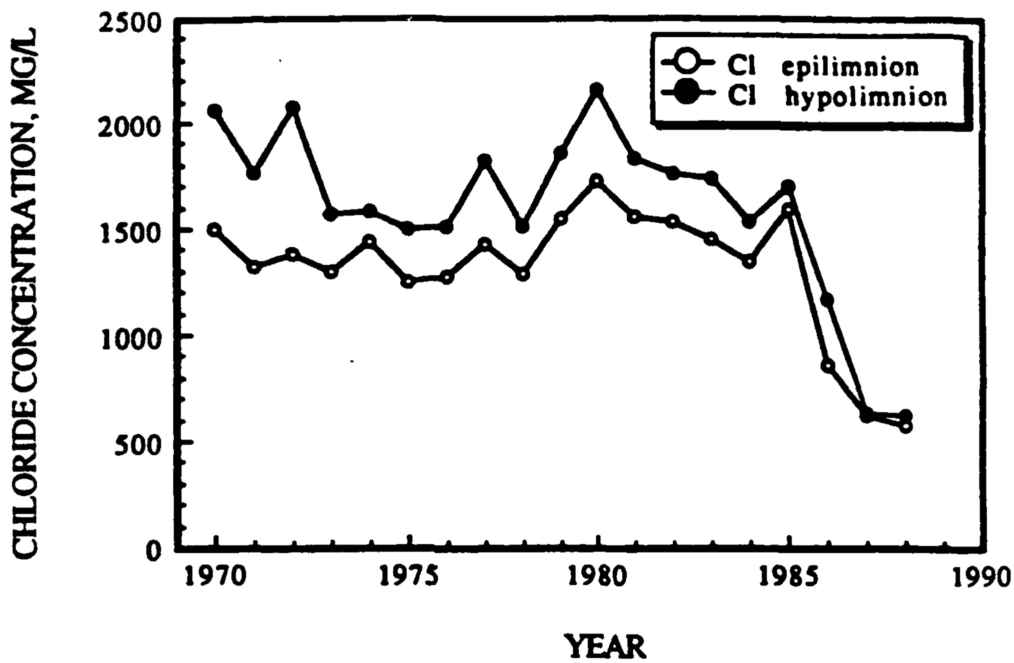
Table 4 Comparison of Ionic Salts in the Hypolimnion and Epilimnion for 1981, 1986, 1987, 1988, and 1989 (mg/l)

Cl^-	1981	1986	1987	1988	1989
Epilimnion	1600 (average)	859	623	590	458
Hypolimnion		1172	629	616	509
Na^+					
Epilimnion	550 (average)	302	251	265	200
Hypolimnion		394	248	274	218
Ca^{2+}					
Epilimnion	500 (average)	256	191	189	159
Hypolimnion		365	208	204	172

Figures 7 through 9 show the general trend for the period of record. It can be seen from these figures that chloride, sodium, and calcium concentrations have decreased significantly since 1985.

2.5 Heavy Metals

The concentrations of heavy metals have varied over the course of the annual lake monitoring program. Lead, chromium, cadmium, zinc, and copper have decreased in both the hypolimnion and epilimnion. These decreases may be attributed to improvements at METRO and other factors such as the use of unleaded fuels and the permit and pretreatment processes.



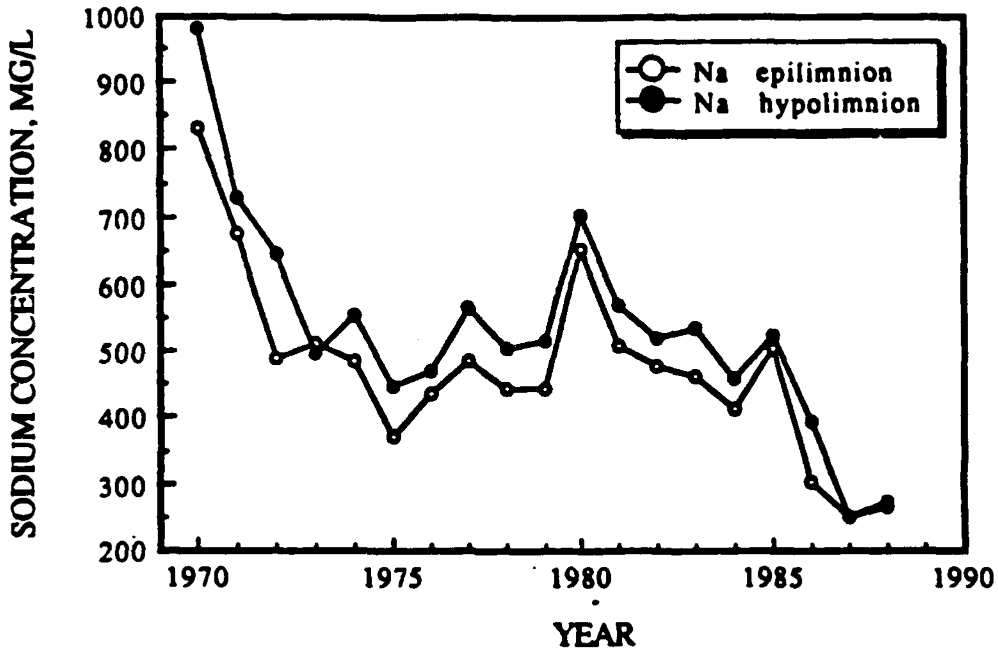
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ANNUAL VOLUME AVERAGED CHLORIDE CONCENTRATION 1970-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 7



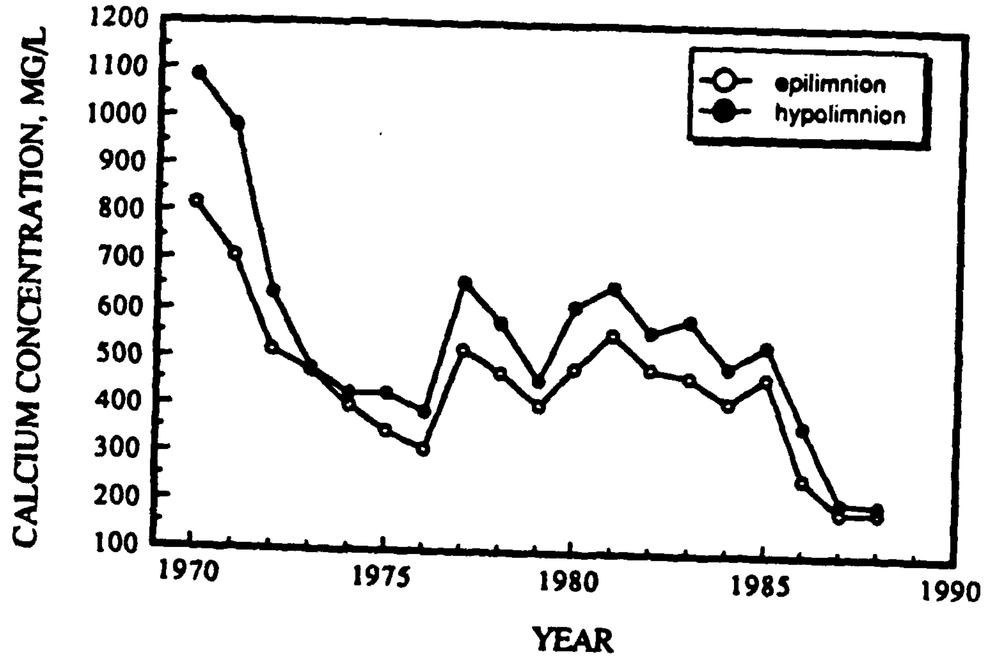
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ANNUAL VOLUME AVERAGED SODIUM CONCENTRATION 1970-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 8



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ANNUAL VOLUME AVERAGED CALCIUM CONCENTRATION 1970-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1990

Figure 9

Particular emphasis has been placed on the mercury contamination. Between 1946 and 1970 large quantities of mercury (75,000 kg) were discharged by the chlor-alkali plant. Reductions in discharge occurred after 1970, however, an increase was measured in the 1980's until the elimination of the discharge in 1989 resulting from the closure of the Linden Chemical Plastics (LCP) plant.

The contamination of the lakes sediments with mercury have been documented by the U.S. Environmental Protection Agency (USEPA) (1973) and the New York State Department of Environmental Conservation (NYSDEC) (1989). Rowell (1990) has shown that mercury concentration in the layers of sediment vary with the Allied chlorine production for that year which each layer represents. One change shown by the sediment cores is that the mercury levels are not the highest at the surface. The concentration increases below the surface indicating a reduction in recent sediment.

A preliminary study was performed in 1989 to assess the seasonal variability in the mercury speciation (Bloom and Effler, 1990). Dissolved and particulate mercury speciation was determined at three depths of the water column. Total mercury, reactive (ionic) mercury, monomethyl mercury, elemental mercury, and dimethyl mercury were determined. Results from this study showed that the water column is contaminated with mercury. A wide variation was detected in concentrations of Hg^{+} and CH_3HgX with time and depth indicating mercury cycling is active and influenced by stratification.

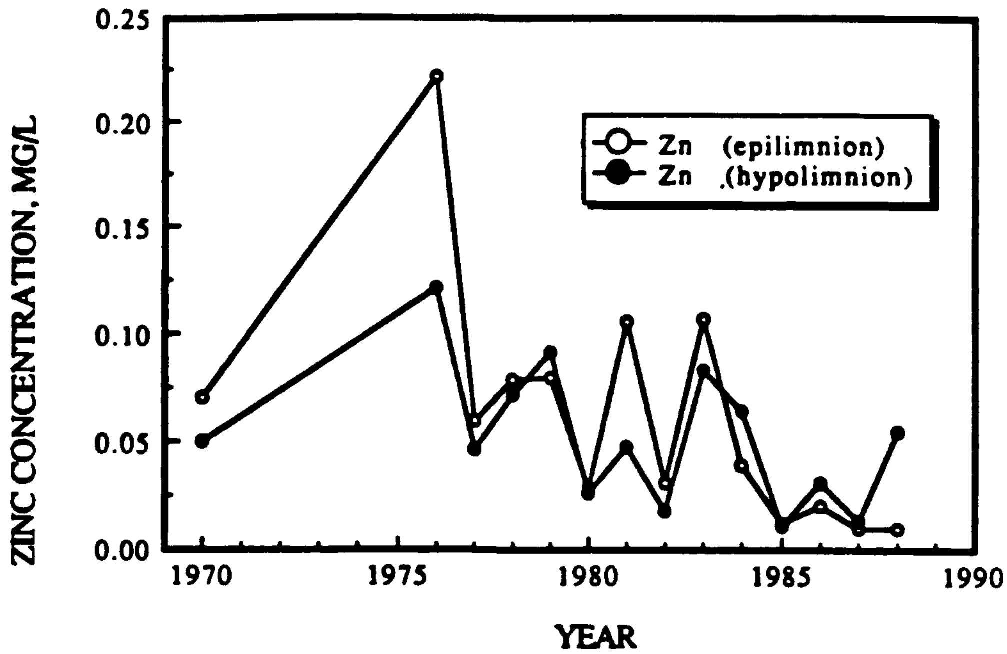
The Onondaga County Department of Drainage and Sanitation monitoring program has collected data for zinc, lead, copper, chromium, and cadmium.

The trends over the period of record are shown on Figures 10 through 14.

2.6 Bacteria

The New York State Department of Health has used various genre of indicator bacteria groups to reflect the presence of pathogenic microorganisms. Based on the presence of bacteria that originate in the human intestinal tract (e.g. fecal coliform bacteria), standards have been developed for the regulation of public water supplies (Onondaga County, 1989) and for the use of contact recreation.

Bacteria loads from the tributaries and the fate of the bacteria in the lake have been monitored extensively. During the summer of 1987, 10 tributary stations and 10 lake stations were monitored each week to measure fecal coliform bacteria inputs from the watershed during wet and dry weather (Auer, 1989). Results from the 1987 monitoring program indicated that the levels of fecal coliform bacteria in the open water of the lake are within the prescribed limits for contact recreation during dry weather periods. Onondaga Creek and Harbor Brook have high concentrations of fecal coliform bacteria during dry weather. These dry weather discharges of Onondaga Creek and Harbor Brook resulted in higher concentrations at the south end of the lake. Storm events caused violations of fecal coliform bacteria standards for contact recreation for large portions of the lake and are highest at the south end of the lake. The increased levels of fecal coliform bacteria at the northern end of the lake are suspected to be contributed by Nine Mile Creek, Sawmill Creek, and Bloody Brook. Results of the 1987 monitoring also showed that following storm events, the lake station concentrations returned to levels that would allow contact recreation within 1 to 3 days following the storm. This may not be typical because 1987 was a dry year. A bacteria model has been developed that is capable of predicting bacteria levels for any set of weather conditions.



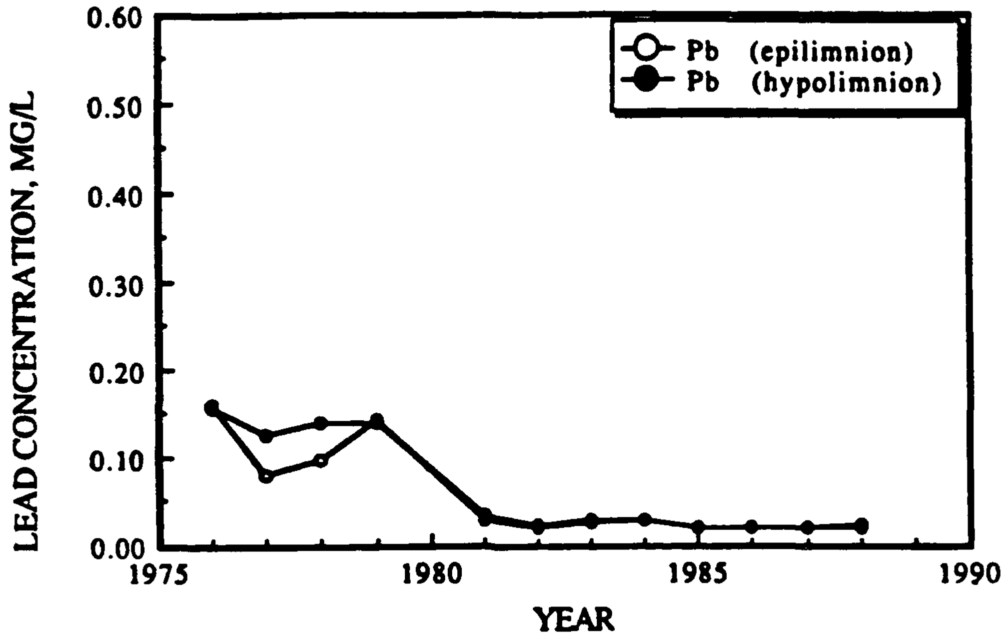
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ZINC CONCENTRATION 1970 & 1976-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 10



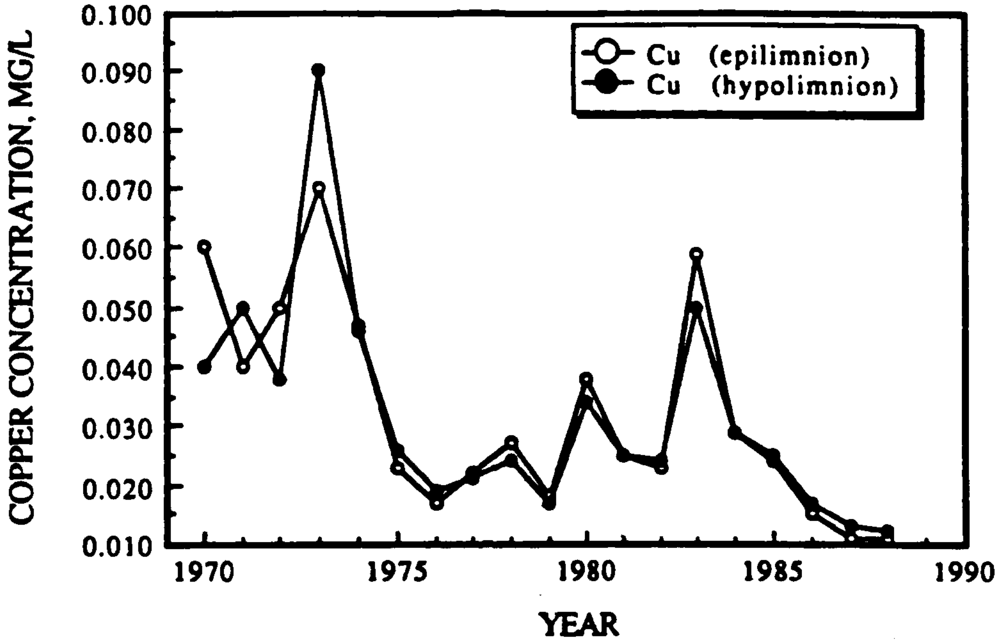
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISANCE REPORT

LEAD CONCENTRATION
1976-1979 1981-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1990

Figure 11



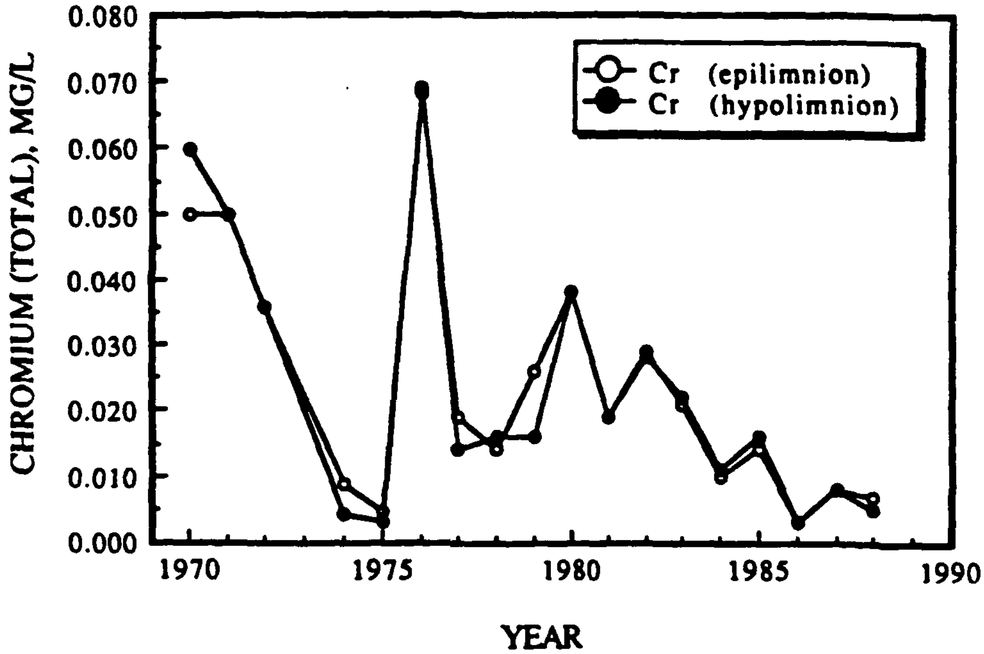
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

COPPER CONCENTRATION
1970 & 1976-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 11



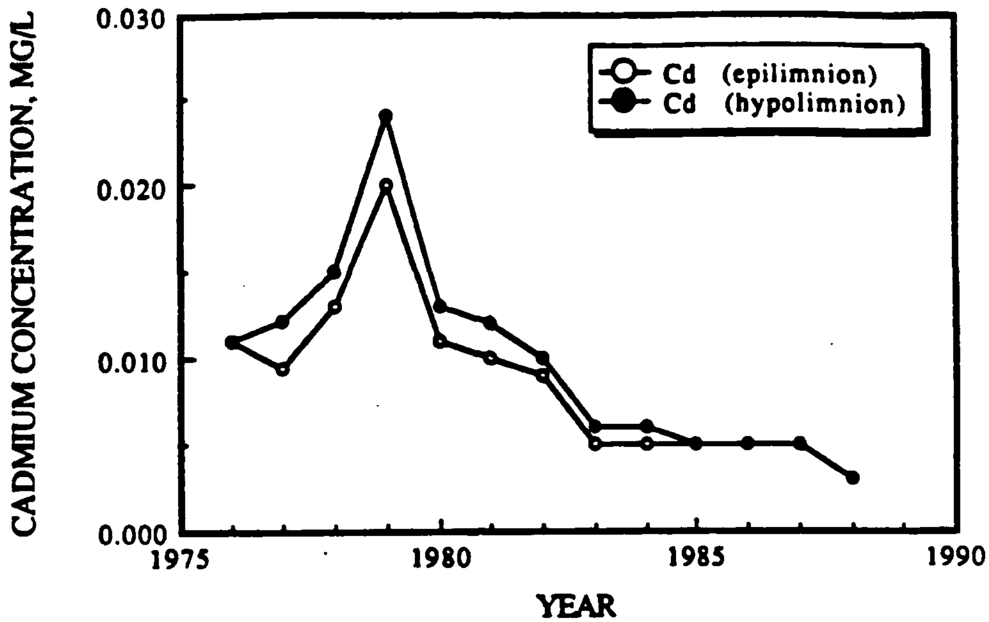
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CHROMIUM CONCENTRATION 1970-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 13



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CADMIUM CONCENTRATION
1976-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 14

The Onondaga County Department of Drainage and Sanitation monitoring program has been collecting data on the trends of fecal coliform bacteria. Figures 15 and 16 show the trends in the volume averaged concentrations of fecal coliform bacteria and fecal strep concentration in the hypolimnion and epilimnion for the entire period of record. It must be noted that these volume-averaged concentrations may be misleading since the values are highly dependent on weather conditions.

2.7 Ammonia Toxicity

Total ammonia nitrogen exists in ionized and unionized form depending on the pH and temperature. It is the unionized form that is potentially toxic to fish and prevents their spawning (Onondaga County, 1989).

The New York State Department of Environmental Conservation (NYSDEC) is currently reviewing their standards for ammonia to protect against chronic ammonia toxicity. The State standard differs from the Federal standard and is currently under review for possible revision. Presently there is an allowable zone of mixing for wastewater effluent to disperse and dilute into the receiving water (Stearns and Wheler, 1988). The present management goal for the METRO discharge for total ammonia under the Federal consent decree has not yet been determined.

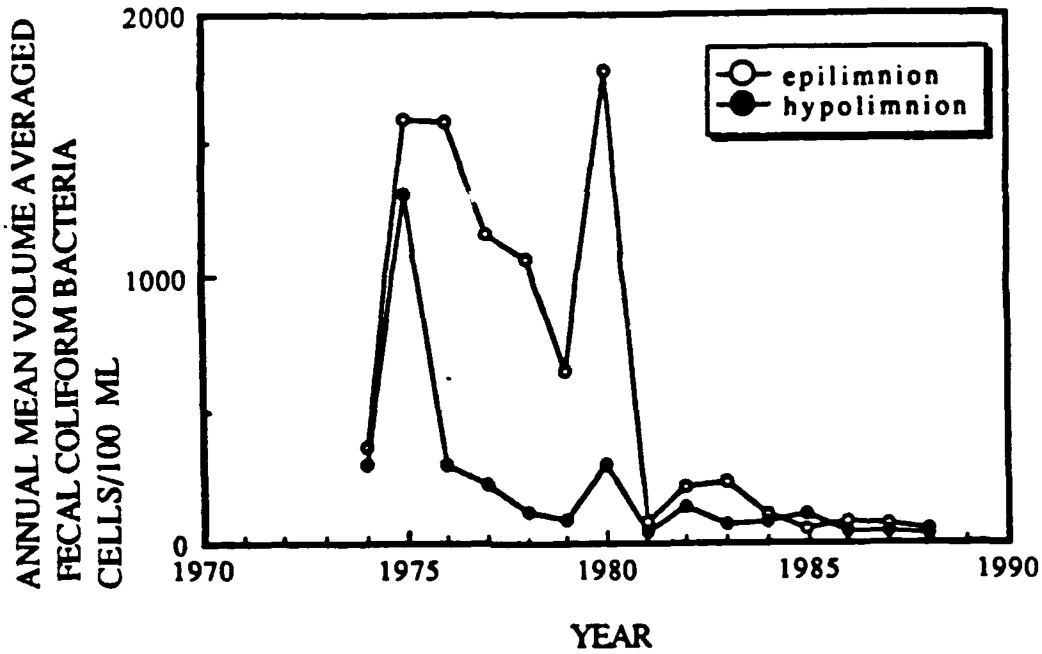
In a study by Effler, Brooks, Auer, and Doerr (1990), the distribution of free ammonia was documented for the period from spring through fall for 1988. Results from this study are discussed below.

In stratified lakes, the distribution of free ammonia varies with depth and time as a result of variations in total ammonia, pH, temperature, and ionic content. The primary sources of total ammonia are inputs from the watershed and decomposition of organic material within the lake. The processes that reduce total ammonia include bacterial nitrification and assimilation by plants. Onondaga Lake is enriched in total ammonia and free ammonia. During the 1988 stratification period, the levels of free ammonia were substantially higher in the upper waters than the lower waters, despite the hypolimnetic enrichment because of the higher pH levels and temperatures in the upper waters. These levels exceed the national chronic toxicity criteria for non-salmonid and salmon fish.

The national acute toxicity criteria for non-salmonids were violated on three occasions during algae blooms during the period of study. Figures 17 and 18 show the 1988 ammonia concentration compared to NYSDEC chronic standards for the hypolimnion and the epilimnion, respectively.

The violations of the acute and chronic toxicity criteria occur due to increase in pH (coupled with high photosynthetic activity) and elevated levels of total ammonia.

The Onondaga County Department of Drainage and Sanitation monitoring program has data from 1972-1988. These data for ammonia are shown in Figure 19. There is no apparent trend in the data.



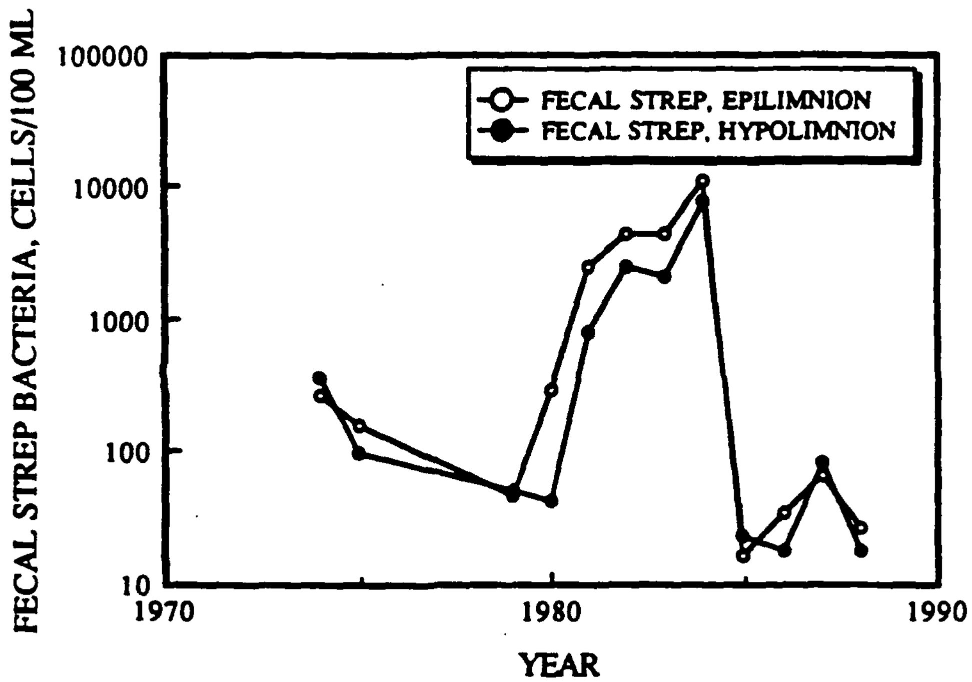
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CONCENTRATION OF FECAL COLIFORM BACTERIA 1974-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 15



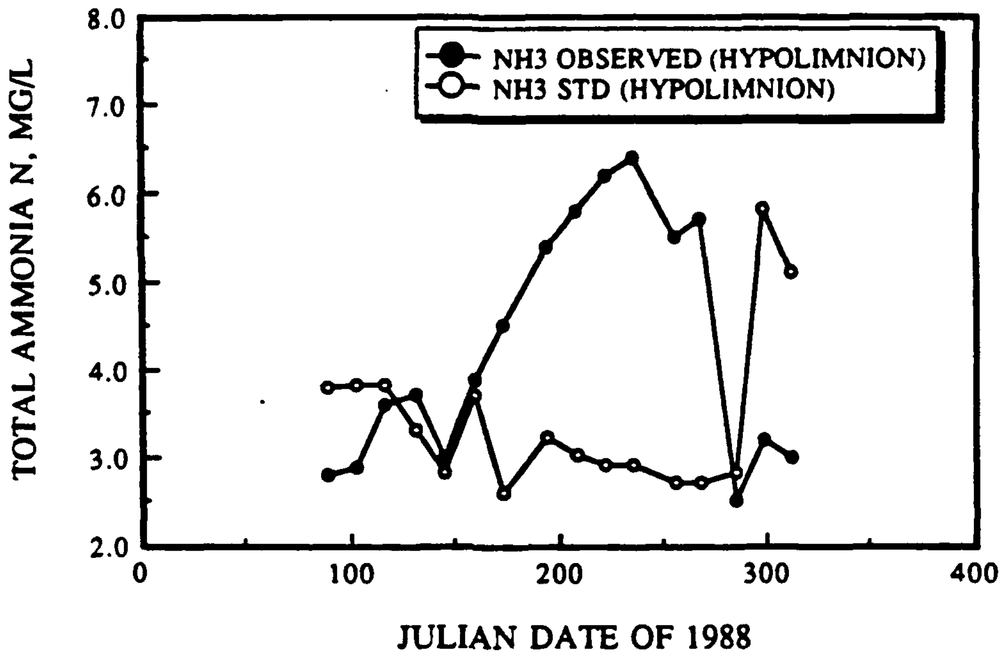
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FECAL STREP CONCENTRATION 1974-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 16



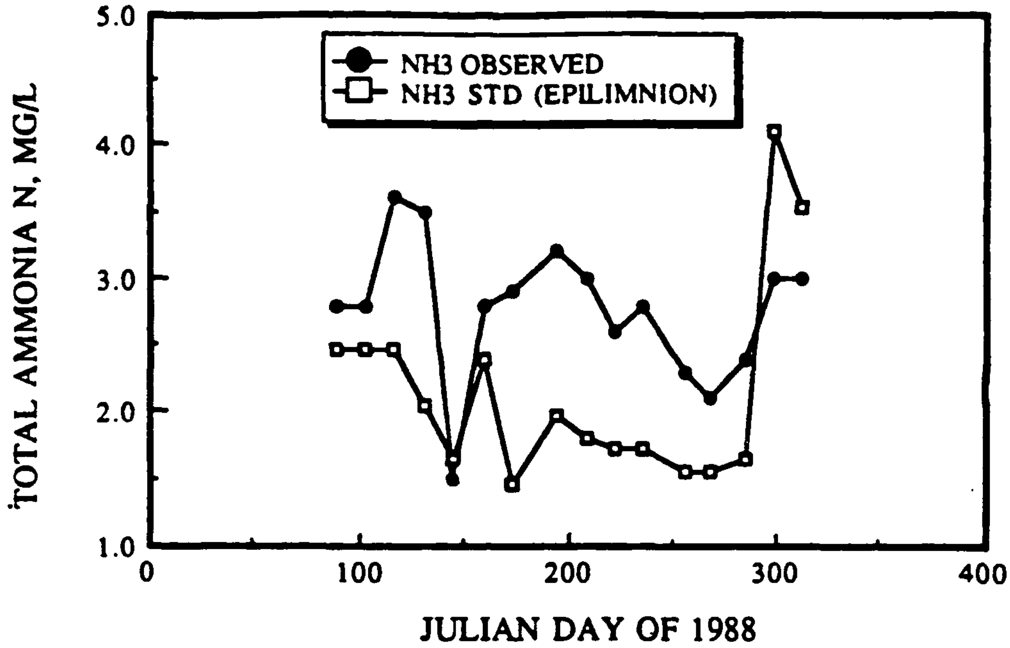
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

1988 HYPOLIMNION AMMONIA COMPARED TO NYSDEC

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1990

Figure 17



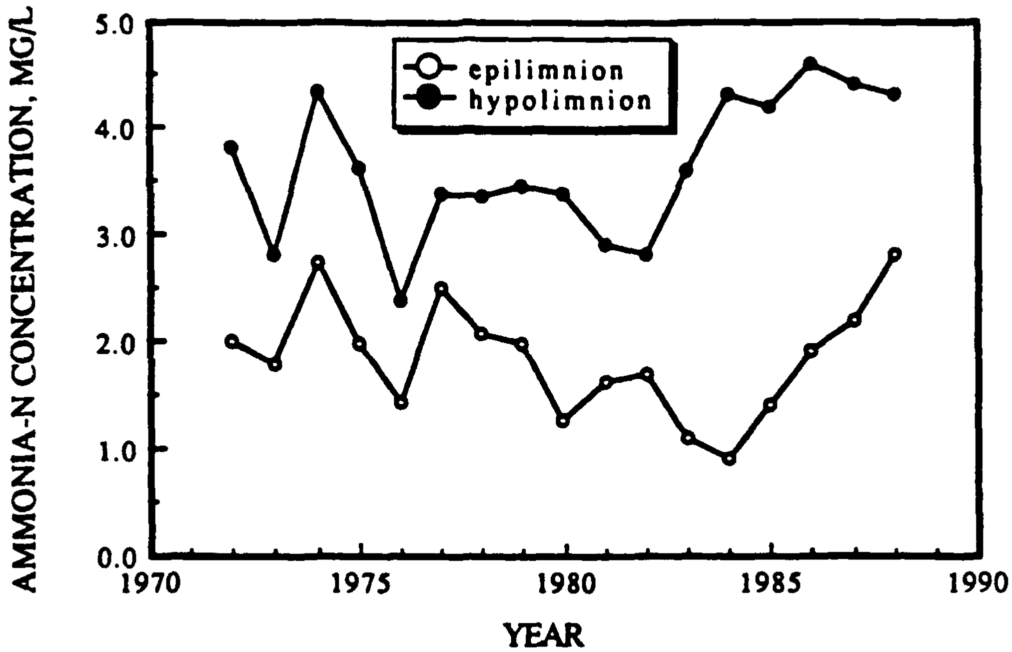
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

1988 EPILIMNION CONCENTRATIONS COMPARED TO NYSDEC

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 18



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISANCE REPORT

AMMONIA CONCENTRATION
1972-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1990

Figure 10

2.8 Transparency

Water transparency is a fundamental measure of water quality and is a function of light attenuation. Light is attenuated by absorption and scattering. A study by Effler, Wodka, and Field, 1984, presents a means of uantifying the contributions of absorption and scattering processes. Based upon the in-lake measurements of apparent optical properties and the authors descriptions of the apparent components of attenuation, it was determined that 60 percent of the light attenuation was produced by phytoplankton and related detritus. Calcium carbonate is a major contributor to attenuation. The origin of the attenuating components is an important consideration in evaluating management alternatives for increasing lake transparency because both dissolved organic carbon (dissolved yellow substances) and calcium carbonate can be received as external loading and/or produced internally. This study indicates that the transparency goals may be attainable through other than nutrient-based restoration efforts.

However, since there was high transparency during the summers of 1987-1990 when there was algae clearing, despite the presence of calcium carbonate, phytoplankton activity seems to strongly influence transparency.

The Onondaga County Department of Drainage and Sanitation annual monitoring program has been measuring Secchi depth as an indicator of transparency. The average depths for the period of record are shown on Figure 20. These readings are taken at biweekly intervals regardless of weather conditions which have a significant effect on them.

3. SOURCES OF POLLUTANTS

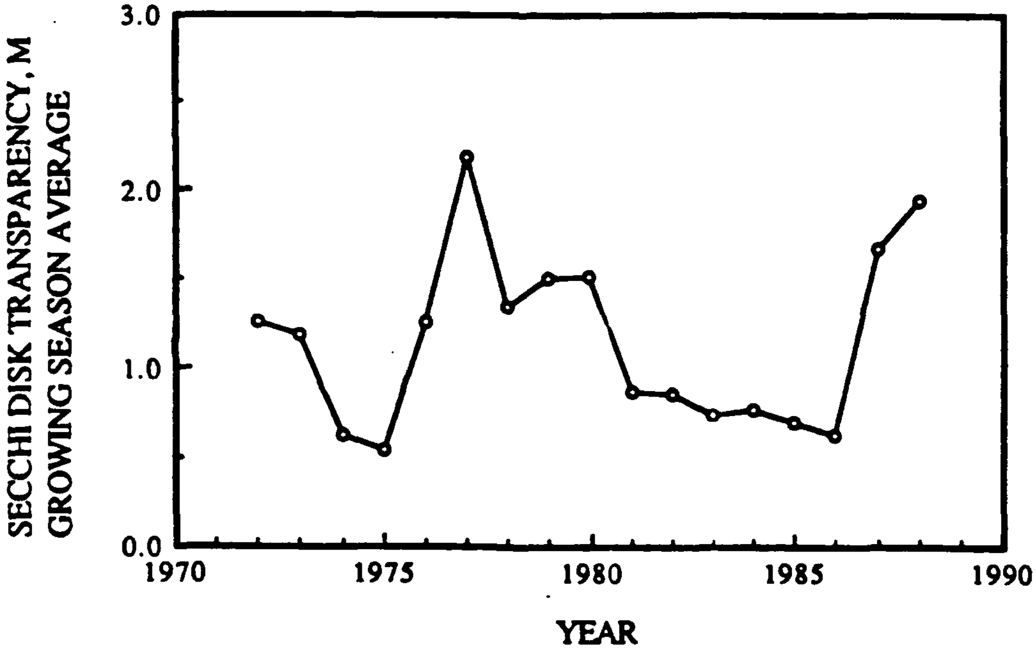
3.1 Sources

3.1.1 Wastewater Treatment Plant

The Metropolitan Syracuse Sewage Treatment Plant (METRO) is an important determinant of Onondaga Lake water quality, as it contributes significant loads of a number of pollutants.

METRO is an 80 MGD advanced wastewater treatment facility which serves the sewage treatment needs of the City of Syracuse and several surrounding communities. Because much of the METRO service area is served by combined sanitary and storm sewers, the plant is designed to provide full treatment up to a projected peak dry weather flow of 120 MGD. Full treatment consists of wastewater screening, grit removal, primary settling, chlorination and tertiary settling. Phosphorus removal is provided by chemical precipitation in the secondary clarifiers using ferrous sulfate.

During wet weather conditions when sewage and stormwater flows exceed 120 MGD, the plant provides partial treatment consisting of wastewater screening, grit removal, primary settling and effluent chlorination for incremental flows exceeding 120 MGD. METRO discharges treated effluent to Onondaga Lake via two outfalls. The main plant outfall is used for flows up to 120 MGD which receive full treatment, and the stormwater outfall is used for incremental flows which exceed 120 MGD and receive only partial treatment.



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SECCHI DEPTH
1972-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 20

METRO effluent BOD5 concentrations have been in compliance with the current interim SPDES permit effluent limit of 21 mg/l for 44 months of the 53-month period of record. In addition, monthly average effluent BOD5 concentrations have been lower than the federally-defined 30 mg/l "secondary treatment" limit for all 53 months. Monthly average effluent suspended solids concentrations have consistently been in the 10-20 mg/l range, well in compliance with the current SPDEC permit effluent limitation of 30 mg/l. Plant effluent total phosphorus concentrations have been in compliance with the current 1 mg/l SPDES permit effluent limitations for 30 of the past 31 months. The current plant SPDEC discharge permit does not contain a limit for either TKN or total ammonia.

The relative impacts of METRO and the other sources of pollutants to the lake (both external and internal) are a major part of the current research monitoring and modeling effort. Historically, METRO was upgraded to provide secondary treatment and more effective disinfection in 1979. The plant was upgraded again in 1981 to provide tertiary treatment to further reduce the total phosphorus loading to the Lake.

The effluent from METRO contributed large percentages of the following pollutants in 1989:

a. Carbon species, including biochemical oxygen demand (BOD), total organic carbon, filtered total organic carbon, total inorganic carbon, and total alkalinity.

b. Phosphorus, both total inorganic phosphorus and orthophosphate.

c. All monitored forms of nitrogen, including ammonia nitrogen, organic nitrogen, total kjeldahl nitrogen, filtered total kjeldahl nitrogen, nitrate nitrogen, and nitrite nitrogen.

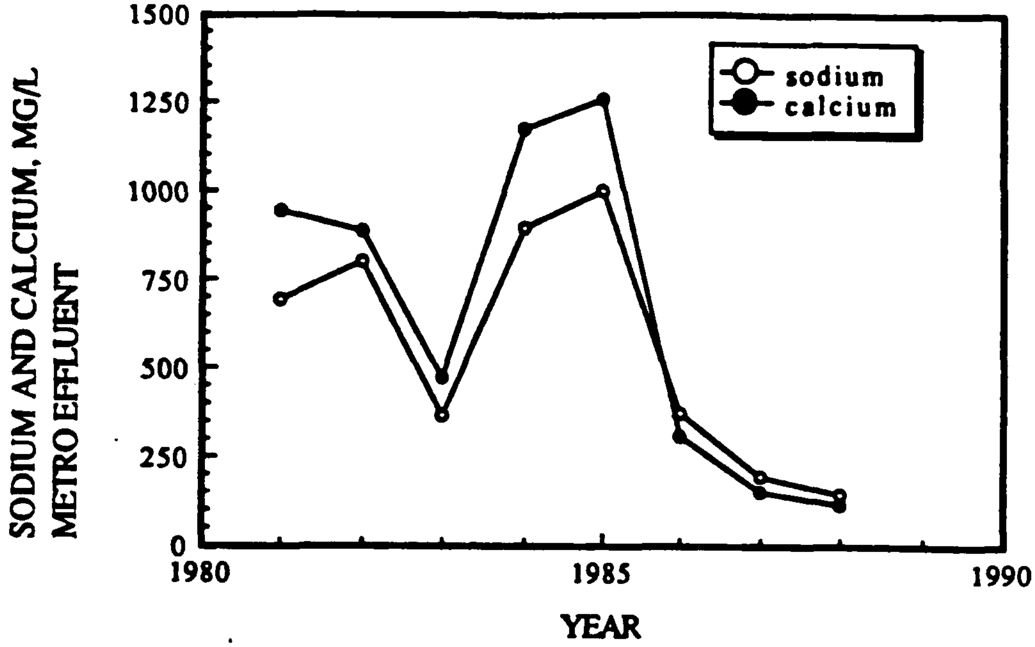
d. Several heavy metals, zinc, lead, copper, chromium, mercury, and cadmium.

With the closure of the Allied Chemical Corporation's Chlor-alkali facility in 1986, the concentrations of sodium and calcium chloride, and specific conductance in the METRO effluent have decreased dramatically (Stearns & Wheler, 1990). Figures 21, 22, and 23 show the reduction in these pollutants. The levels in the METRO effluent are still somewhat elevated because Allied still discharges wastebed overflow and runoff to the head end of METRO.

3.1.2 Combined Sewer Overflows

The importance of storm and combined sewer overflow (CSO) as a major source of contaminants to Onondaga Lake has long been recognized. The significance of CSO has increased as a result of increased loadings of sanitary wastewater and stormwater generated from new residential, commercial, and industrial developments to the finite capacity of the existing combined sewer system. There are 45 CSOs which discharge to Onondaga Creek and 19 CSOs that discharge to Harbor Brook. Ley Creek receives discharges from 2 CSOs. These CSOs are a source of fecal coliform bacteria, BOD, nitrogen, phosphorus, and a variety of toxic pollutants discharged to the combined sewer by industrial users of the collection system.

In the early 1980's, as Phase I of a CSO Master Plan for Onondaga County, the concept of a Best Management Practice (BMP) Policy offered an immediate means of optimizing the existing system's conveyance capacity, while aiding in the development of a long-term structurally intensive solution.



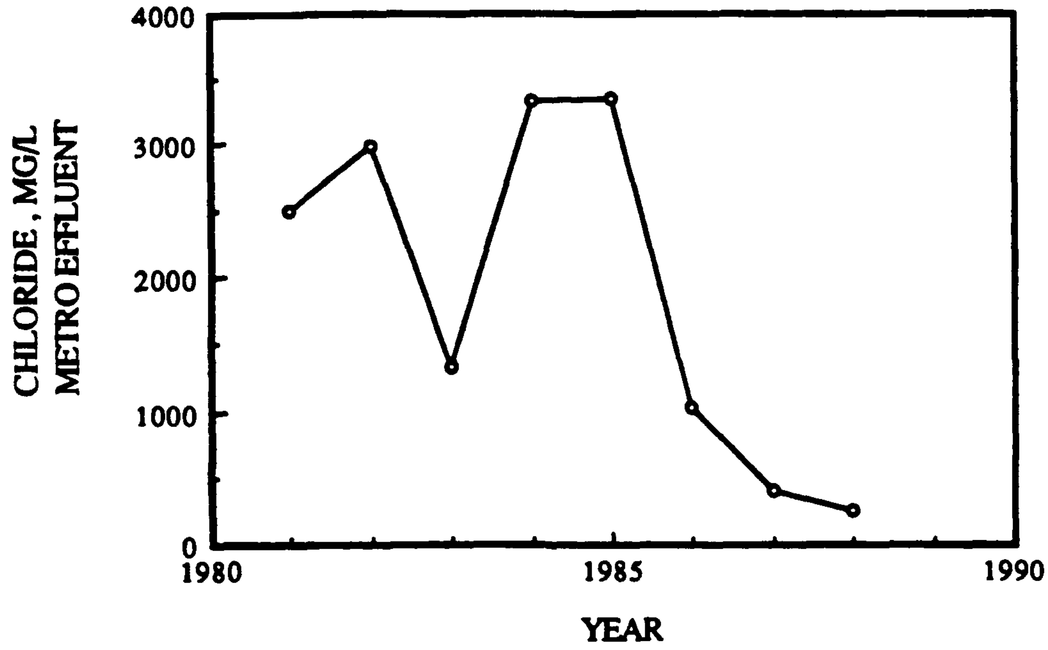
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SODIUM AND CALCIUM CONCENTRATION METRO 1981-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 21



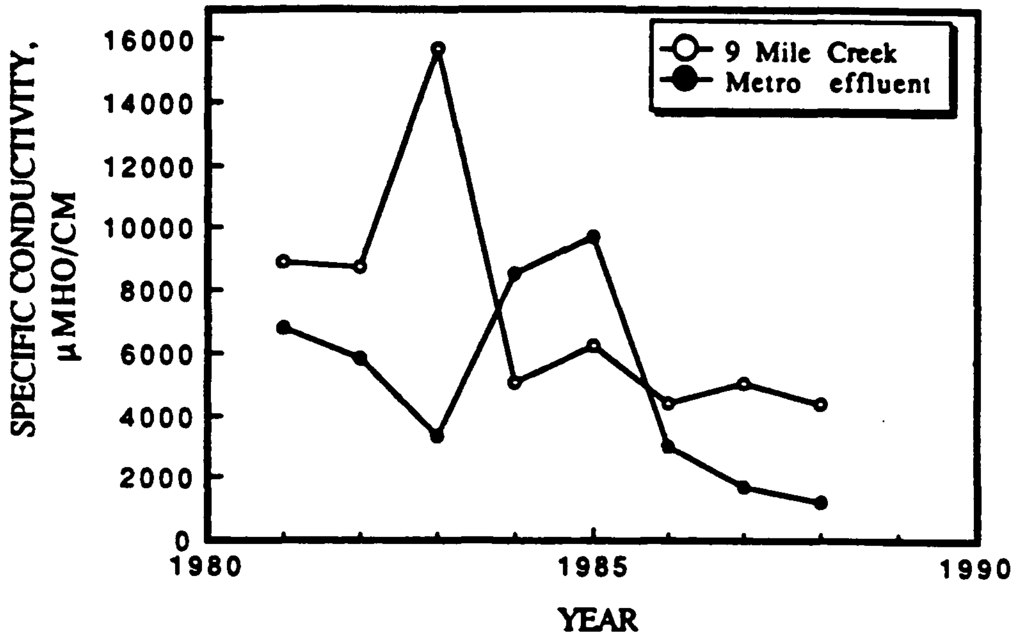
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CHLORIDE CONCENTRATION
METRO
1981-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 22



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SPECIFIC CONDUCTIVITY NINE MILE CREEK AND METRO EFFLUENT 1981-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 23

As a first phase solution, the BMP approach to CSO abatement was directed towards increasing the existing system's conveyance capacity at a minimal cost. Based on the system's maximum potential capacities and overall hydraulic profile, BMP modifications were formulated, tested, and evaluated according to their cost, feasibility, and success in reducing total overflow volume.

Initial stages of the BMP abatement program evaluated different BMP modifications as implemented individually. Results of these tests led to a determination of a BMP program, optimized by the integration of four different BMP schemes.

As different BMP schemes were formulated, their effectiveness was tested through the use of a comprehensive mathematical model. The computer model chosen for these evaluations was the USEPA Storm Water Management Model (SWMM). With the basis of input being a rainfall hyetograph and sewerage system and drainage area characteristics, SWMM simulated real storm events. Initially, various storm events were simulated on the existing system, and on systems redefined to represent suggested BMP modifications. Comparisons were then made as to how different modified systems managed the storms, and how effective they were in attenuating CSO discharges.

A number of sewer system improvements were implemented within the city of Syracuse combined sewer collection and conveyance system. It was projected during the CSO facilities planning phase that significant reductions in the frequencies and volumes of CSO discharges could be realized by optimizing the performance capabilities of various parts of the sewer system.

A number of individual, but related sewer system improvements were defined as being effective in reducing CSO discharges. For this project, the types of improvements were divided into six categories, based on similarity and/or for construction bidding purposes:

(1) Overflow Weir and Dam Modifications - Increasing the elevation of overflow weirs and dams would result in containment of a greater portion of wet weather flow within the interceptors and trunk sewers prior to the onset of overflows. However, since the available capacity of the sewer system is limited, it was projected that these improvements would be most effective for the less intense and more frequently occurring storm events.

(2) Increased Regulator Capacities - By increasing the size of the pipes and/or orifices between the trunk sewers and the interceptors, a greater quantity of wet weather flows could be conveyed through the system for treatment. Again, these improvements would be expected to be more effective for less intense, more frequently occurring storm events due to limited conveyance capacity in the interceptor system.

(3) Conveyance System Cleaning Program - By removing materials and debris which have accumulated and settled within the trunk sewers and interceptors, additional capacity for conveyance of wet weather flows would be made available. This additional capacity would be limited by the physical characteristics of the sewers and the capacity required for dry weather flow conveyance.

(4) Sewer Rehabilitation and Replacement - Rehabilitation and/or replacement of portions of the Harbor Brook Interceptor Sewer was recommended to reduce hydraulic bottlenecks and increase the useful life of the sewer system. By implementing these improvements, better performance during dry weather was projected to be achieved and additional capacity for wet weather flow conveyance would be provided.

(5) In-System Storage - By utilizing an available in-ground storm sewer, a substantial volume of in-system storage was provided for temporary storage of CSO - the Erie Boulevard Storm Sewer. When interceptor capacity becomes available after storm events, the stored CSO is bled back into the interceptor for treatment at METRO. Due to equipment problems, this system was not operating properly for a time.

(6) In-System Grit Facilities - Once the conveyance system cleaning program was implemented and the total conveyance capacity of the major interceptors restored to its full potential, it was desired to maintain this full capacity in the future. Therefore, six grit removal facilities were constructed within the sewer system to provide for convenient points for grit particles to settle and be removed, thereby reducing the instances of solids deposits and resulting conveyance restrictions in the sewers themselves.

A Post-BMP assessment conducted by O'Brien & Gere in 1987 demonstrated that there are measurable improvements in system performance and water quality resulting from the various collection system improvements. Another post-BMP assessment made by Moffa & Associates, through a flow monitoring program in 1987 which was representative of 30 percent of the combined sewered area, estimated that over 90 percent of the annual volume of combined sewer overflow that previously discharged to Harbor Brook and Onondaga Creek and then to the Lake is now diverted to METRO. Much of the improvement was realized by eliminating dry weather raw sewage discharges.

Phase II of the CSO Master Plan for Onondaga County was to include installation of 21,000 linear feet of CSO transmission pipelines, construction of six satellite CSO treatment facilities, and modification of two existing demonstration CSO treatment facilities. Subsequent to preparation of the Master Plan, an additional CSO abatement strategy known as the "Flow Balancing Method" was investigated. This plan was to consist of continued use of the streams as sewers and flexible containment structures installed at the mouths of Onondaga Creek and Harbor Brook to allow for chlorination. At the current time, Phase II has not been implemented nor has final design of any of the Phase II elements been initiated. However, an updated CSO Facilities Plan is currently on-going which will provide several CSO abatement alternatives.

3.1.3 Industrial

Historically, Onondaga Lake has served an important industrial function, both as a source of process water and as a receiving body for process wastes. Two of the Syracuse areas largest industries, Allied Chemical Corporation (producer of soda ash and a number of other carbonate and chloride products; now closed) and Crucible Specialty Metals (steel foundry and rolling mill), as well as Linden Chemicals and Plastics (LCP also closed but has applied for a permit to reopen) were sited along the Onondaga Lake shoreline for these purposes.

Allied Chemical, which closed in 1986, used about 80 million gallons of water per day from Onondaga Lake as cooling water for its manufacturing operations. Allied treated the water from the lake with large amounts of chlorine to remove algae and bacteria that interfered with its use of the water.

Another Allied discharge to the lake was the effluent from the waste beds which discharged to the lake via Nine Mile Creek until 1981 when the waste bed overflow was diverted to the METRO for use in phosphorus removal as part of the tertiary treatment process. This was discontinued upon plant closure, but a substantial loading of sodium, calcium, and chlorides to the lake (as much as 800,000 pounds daily have been measured in Nine Mile Creek, down from 8-10 million pounds during plant operations) still occurs as runoff and groundwater flow from the waste beds area (Onondaga County, 1989).

Several other industries discharge into tributaries of Onondaga Lake, either directly or through municipal sewage treatment plants. They are listed on Table 5. In addition, some 400 businesses and industries discharge wastewaters into the METRO sewer system. These discharges are regulated under the County Department of Drainage and Sanitation industrial wastewater pretreatment program.

Eight facilities are regulated under the State SPDES program for their stormwater runoff and spill discharges.

Table 5 Significant Industrial Dischargers

Bristol-Meyers Squibb

GMC Fisher Guide Plant

Carrier Corp.

Oberdorfer Foundries

Sun Refining & Marketing

Chrysler Corporation

Syracuse China Corp.

Roth Brothers Smelting Corp.

Otisco Lake - Water Treatment Plant

Hertz Corp.

Crucible Specialty Metals

GE

3.1.4 Tributaries

The Onondaga County Department of Drainage and Sanitation has been monitoring five tributaries to Onondaga Lake as part of their annual monitoring program. The information presented below is based on the results of the monitoring. In addition to the five natural tributaries, the lake outlet, and the effluent streams from METRO are also part of the monitoring program. The seven natural tributaries to the lake, not all part of the monitoring program, include Onondaga Creek, Nine Mile Creek, Harbor Brook, Ley Creek, Tributary 5A, Sawmill Creek, and Bloody Brook.

The major sources of water to the lake in terms of approximate annual percent contribution are Nine Mile Creek (40%), Onondaga Creek (35%), and Metropolitan Sewage Treatment Plant (METRO, 15%), with Ley Creek, Harbor Brook, and the other small tributaries making up the remaining 10 percent. These are annual values and are highly variable during the year. For instance, during the summer months, METRO can be the major contributor.

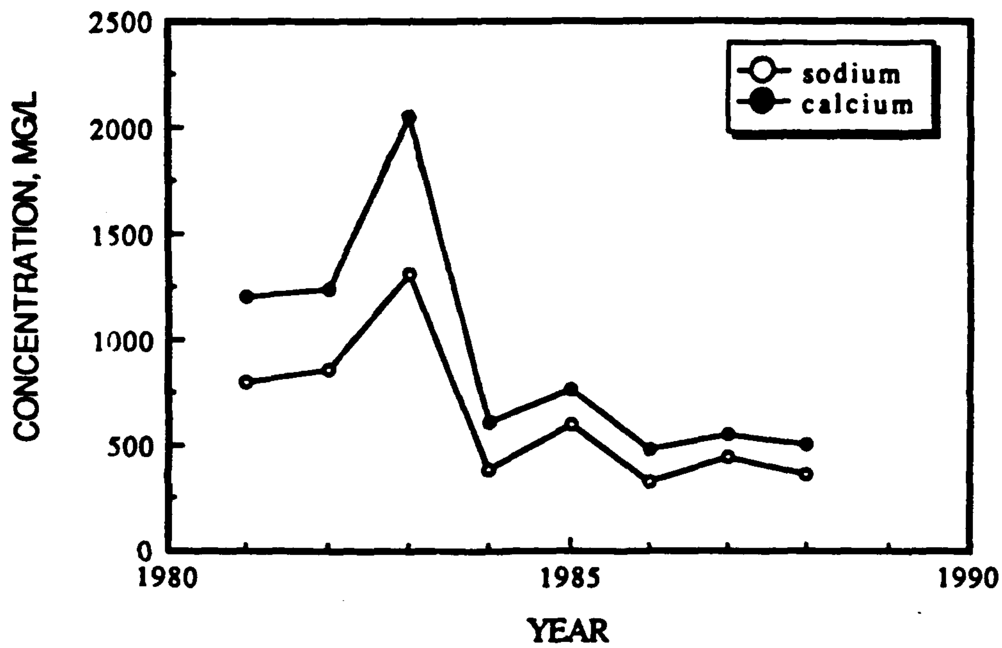
3.1.4.1 Nine Mile Creek

Nine Mile Creek has a watershed area of 124.7 square miles, with Otisco Lake in its headwaters. The creek receives secondary effluent treated wastewater from the village of Marcellus, and overflow and infiltration from the waste beds of Allied Chemical Corporation. Nine Mile Creek also receives or will shortly receive waste from a variety of industries via Geddes Brook and the "West Flume."

Data from the 1988 monitoring program show that Nine Mile Creek is the largest source of inorganic salts (sodium, calcium, and chloride) to Onondaga Lake. Figures 24 and 25 show the changes in concentration in these salts from 1981 through 1988. Since the closure of Allied in 1986, the concentrations of sodium, calcium, and chloride have diminished. Results from the 1988 data collection showed elevated concentrations of zinc, lead, copper, chromium, cadmium, and mercury.

Nine Mile Creek is the fourth largest contributor of total phosphorus to the lake. The average mass loading rate of phosphorus is 15 pounds/day.

Table 6 shows the results of the 1988 influent discharge mass loading in percent contributions. Details of each tributary and the METRO inflow are discussed below.



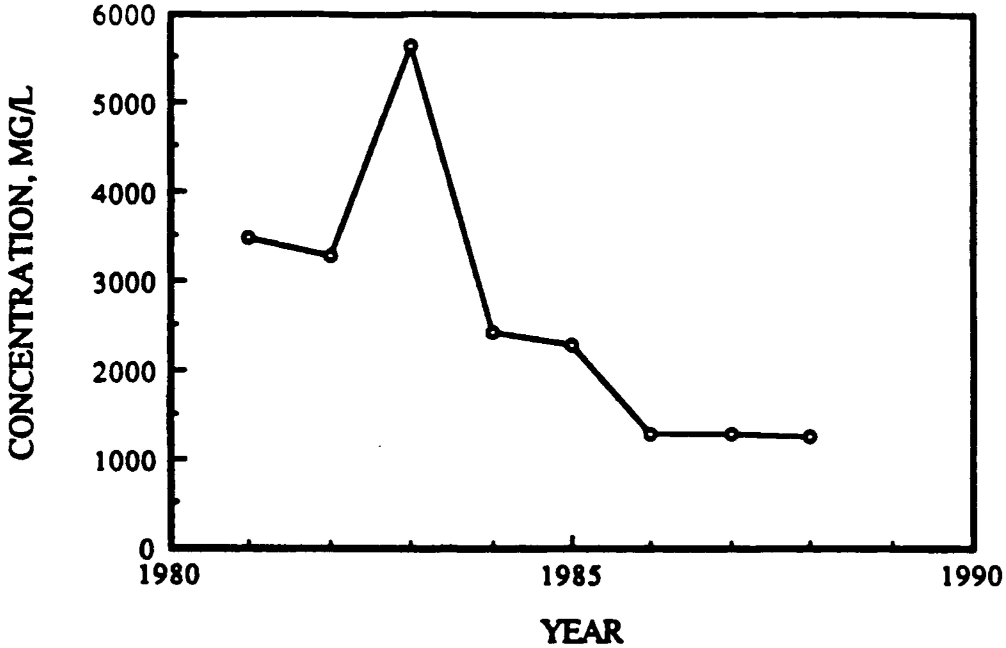
From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SODIUM AND CALCIUM CONCENTRATION NINE MILE CREEK 1981-1988

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 24



From: Stearns and Wheler, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

**CHLORIDE CONCENTRATION
NINE MILE CREEK
1981-1988**

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 25

Table 6 1988 Influent Discharge Survey
Mass Loading Percent Contributions

Parameter	Ley Creek	Metro	Onondaga Creek	Harbor Brook	East Flume*	Nine Mile Creek	Tributary 5A
Flow (MGD)	21.2	77.3	66.1	4.2	2.75	56.3	0.94
DO	8.7	28.9	33.4	1.9	<.1	26.8	0.3
BOD_5	18.2	68.4	7.9	0.4	0.2	4.7	0.2
Cl	4.4	16.6	22.9	0.7	0.1	55.1	0.2
Total alkalinity	8.7	34.1	31.0	2.1	0.4	23.4	0.3
SiO_2	9.6	42.1	27.5	1.7	0.7	18.0	0.4
TIP	8.0	76.9	9.5	0.4	<.1	5.2	0.1
Ortho-P	7.0	81.8	7.3	0.3	<.1	3.7	0.1
NH_3-N	2.0	89.4	1.4	0.1	3.3	3.8	<.1
Org-N	10.3	68.8	11.2	0.8	1.2	7.5	0.2
TKN	3.6	85.6	3.2	0.2	2.9	4.4	0.1
Fil. TKN	3.1	86.2	3.3	0.2	2.8	4.3	0.1
NO_3-N	2.7	60.8	19.2	1.7	1.9	12.5	1.2
NO_2-N	1.0	82.3	1.4	0.1	12.8	2.3	0.2
Fecal coliform	11.5	0.3	72.3	0.6	2.2	13.1	<.1
Fecal strep	87.4	1.9	8.3	0.4	0.8	1.2	<.1
Na	5.7	22.9	32.7	0.8	0.6	37.0	0.3
Ca	5.4	19.1	18.3	2.3	<.1	55.1	0.2
Zn	8.1	50.6	13.1	1.0	<.1	28.2	0.2
Pb	9.2	33.6	30.7	2.1	<.1	28.0	0.5
Cu	6.6	47.3	21.9	2.3	<.1	27.3	0.4
Cr	11.8	38.8	27.8	1.5	<.1	17.5	2.7
Cd	9.2	31.6	29.8	1.9	<.1	27.2	0.4
Hg	3.9	14.5	12.0	0.8	<.1	68.6	0.2
TOC	18.5	61.1	8.9	3.1	<.1	8.2	0.2
Fil. TOC	18.7	63.9	8.2	0.6	0.1	8.3	0.2
TIC	9.3	33.0	31.1	2.1	0.3	24.0	0.2

*East Flume loading data are estimates. See text for details.
From: Stearns and Wheler, 1990
Units in percent contribution

3.1.4.2 Onondaga Creek

Onondaga Creek has a drainage area of 115.1 square miles. The watershed is a mix of urban and industrial where it flows through the city of Syracuse and agricultural as it flows through the Tully Valley. There are a total of 45 combined sewer overflows that discharge into the creek.

Based on the 1988 data, the water quality is considered degraded with elevated concentrations of fecal coliform bacteria, salts, lead, copper, and chromium and suspended sediment. Due to the large volume of flow this creek is a significant contributor of these parameters.

Because Onondaga Creek is the second greatest contributor of phosphorus, a comparative analysis was performed by UFI, 1990, of the upstream (Dorwin Avenue) and downstream (Spencer Street) gaging stations for the period from

April 1988 through October 1989. The average total phosphorus concentration at Dorwin Avenue was 0.061 mg/l while the flow weighted average was 0.282. The range in concentration was 0.004-0.870 mg/l. Over the same period, the average concentration at Spencer Street was 0.300 mg/l with the range from 0.010-4.300 mg/l and flow weighted average of 0.717. The average concentration at Dorwin Street was 13 percent of that at Spencer Street while the flow weighted average was 39 percent. The Dorwin Avenue observations exceeded 0.2 mg/l less than 1 percent of the time whereas the Spencer Street observations exceeded 0.2 mg/liter, 40 percent of the time. An analysis of the data from June 1988 through September 1988 showed the average total phosphorus load at Dorwin Avenue was 3.3 kg/day. At Spencer Street, the average total phosphorus load was 89.7 kg/day which is 96 percent of the total load.

The difference in loads has been attributed to combined sewer discharges with an ancillary contribution of direct urban runoff. A more detailed analysis of phosphorus loading is presented in Section 6.1.3.

3.1.4.3 Ley Creek

Ley Creek drains a watershed area of 29.9 square miles on the east of Onondaga Lake. Most of the watershed is residential and industrial in nature; however, the upper reaches include some agricultural land. Two combined sewer overflows (CSO's) enter Ley Creek as well as two sanitary sewer overflows at the Brooklawn and Ley Creek pump stations. These two sanitary sewer overflows will be abated by a parallel sewer/pump station project nearing completion. Two closed sanitary landfills are located adjacent to Ley Creek. The 1988 data for Ley Creek are affected by a break in a 42-inch force main that resulted in a discharge of untreated sewage to the stream. The concentrations of fecal coliform bacteria, biochemical oxygen demand (BOD), ammonia nitrogen (N), organic N, total kjeldahl N, and phosphorus are elevated due to the break.

Also, the two sanitary landfills that are located adjacent to Ley Creek may be contributing varying amounts of organic materials to the stream which would not be associated with the indicator bacteria. This was suggested in the 1988 monitoring report (Stearns and Wheler, 1990).

The confidence in the loadings for Ley Creek is low because the USGS gaging station is rated poor due to the backwater affect from the lake.

3.1.4.4 Harbor Brook

Harbor Brook drains a watershed of 11.3 square miles, extending to the southwest of the lake. The upper reaches of the watershed is dominated by agricultural land while the lower reaches receive urban runoff. There are 19 CSOs that discharge into Harbor Brook as well as the sanitary overflows from the Hillcrest and Brookside pump stations.

Results from the 1988 monitoring program show elevated concentrations of total inorganic carbon, particulate organic carbon, copper, and lead. Harbor Brook contributes a relatively small percentage of the total load to Onondaga Lake. It is possible that the loads from this source may be underestimated due to the nature of the annual monitoring program. This is due to the fact that sampling is done bi-weekly rather than based on storm events which impact on the CSOs.

3.1.4.5 East Flume

The East Flume had been an industrial discharge point for Allied Signal Inc. and a variety of other industries. During the operation of Allied, the East Flume was a waste heat and process discharge. A thermal diffuser was constructed sometime ago. Since the closure of Allied, the average temperature in the East Flume has decreased.

Some of the 1988 data from the East Flume show lower concentrations of the measured contaminants than the lake. Another problem occurred with the loadings because of the uncertainty with the gage data. There is a backwater affect from the lake.

As a result of the uncertainties and discrepancies, the data from the East Flume can be used only as an indicator to violations of the SPDES permits. The 1988 data indicate that ammonia, nitrite, and nitrate are contributed to the lake from the activities of the remaining industries.

3.1.4.6 Tributary 5A

Tributary 5A is an outlet for Crucible Steel, a steel manufacturing facility and Allied Signal. It also drains the back side of the Tar Beds and may intercept contaminated groundwater. The total flow to Onondaga Lake is relatively low. In the past, this outlet has contributed significant amounts of iron, chromium, and copper to the lake. The wastewater has been treated since 1974, thereby reducing the loads. The data are used primarily for surveillance and the results of the 1988 data show low concentrations for all parameters.

3.1.4.7 Sawmill Creek

Sawmill Creek has a very small watershed and receives no significant pollutant point sources. The outlet has not been monitored.

3.1.4.8 Bloody Brook

The Bloody Brook watershed, 4.5 square miles, extends to the northeast from about the midsection of the east shore of Onondaga Lake. The tributary receives some treated coolant and wastewaters from the General Electric Corporation's Park complex (Bloomfield, 1978). Presently this stream receives raw sewage from the Liverpool pump station. In the past (pre 1985) it had been worse because 2 MGD of dry weather flow was diverted from the Ley Creek service area to this pump station, creating an almost continuous dry weather raw sewage discharge. This pump station is presently being upgraded and will be complete by mid-1991.

3.1.5 Old Disposal Sites

One of the significant sources of pollutants to Onondaga Lake is from the old Allied-Signal waste disposal beds (historically referred to as Solvay waste beds). Information on these sites presented in this section is up-to-date as of this writing. The largest and youngest of the waste beds are located within the Nine Mile Creek Valley with progressively older and smaller waste beds along the shores of Onondaga Lake from the mouth of Nine Mile Creek southeastward to the southwest end of the lake.

The waste material, known as Solvay waste, resulted from the Solvay process which utilized salt brine with limestone to produce sodium carbonate (soda ash). It is composed of calcium carbonate, calcium silicate, and magnesium hydroxide with some carbonate, sulfate salts, and metal oxides. The material was deposited in waste beds comprised of a slurry of 5 to 10 percent solids. Solids settled out in waste beds and the relatively clear supernatant was discharged to surface waters of the State of New York through drop inlets and a circumferential collection system. Figure 26 shows the general area of the Allied disposal sites.

In addition to the Solvay process waste beds, Allied used other sites around the lake for waste disposal. Specific sites are shown on Figure 27. A 22 acre site (Tar Bed Site) was used between 1917-1920 for the disposal of a tar-like waste from its former benzene related operations. The wastes have contaminated the groundwater with benzene, toluene, and naphthalene and are suspected to be migrating toward the lake and toward Tributary 5A (Blasland, Bouck, and Lee, 1989).

Based upon the hydrogeologic assessment of the Allied waste beds, performed by Blasland and Bouck Engineers and historical information, it appears that there are no significant quantities of Solvay waste in areas southeast of Hiawatha Boulevard. There was no indication of Solvay waste in areas designated OLF (Onondaga Lakefront) on the northeast and southwest sides of the lake (Basland, Bouck, and Lee 1989).

Periodic monitoring has indicated that Nine Mile Creek has been a significant contributor of chlorides to Onondaga Lake. The sources into Nine Mile Creek are Waste Beds 9-15, Geddes Brook, and groundwater. The sampling program indicates that leachate samples from the waste beds show a decrease in the concentration of chloride, calcium, and sodium with increasing age of the waste bed. The chloride loading has decreased from 4,000 tons/day in the 1980's to 400 tons/day in 1987 (Blasland, Bouck, and Lee, 1989), corresponding to the closure of the active Allied Operation.

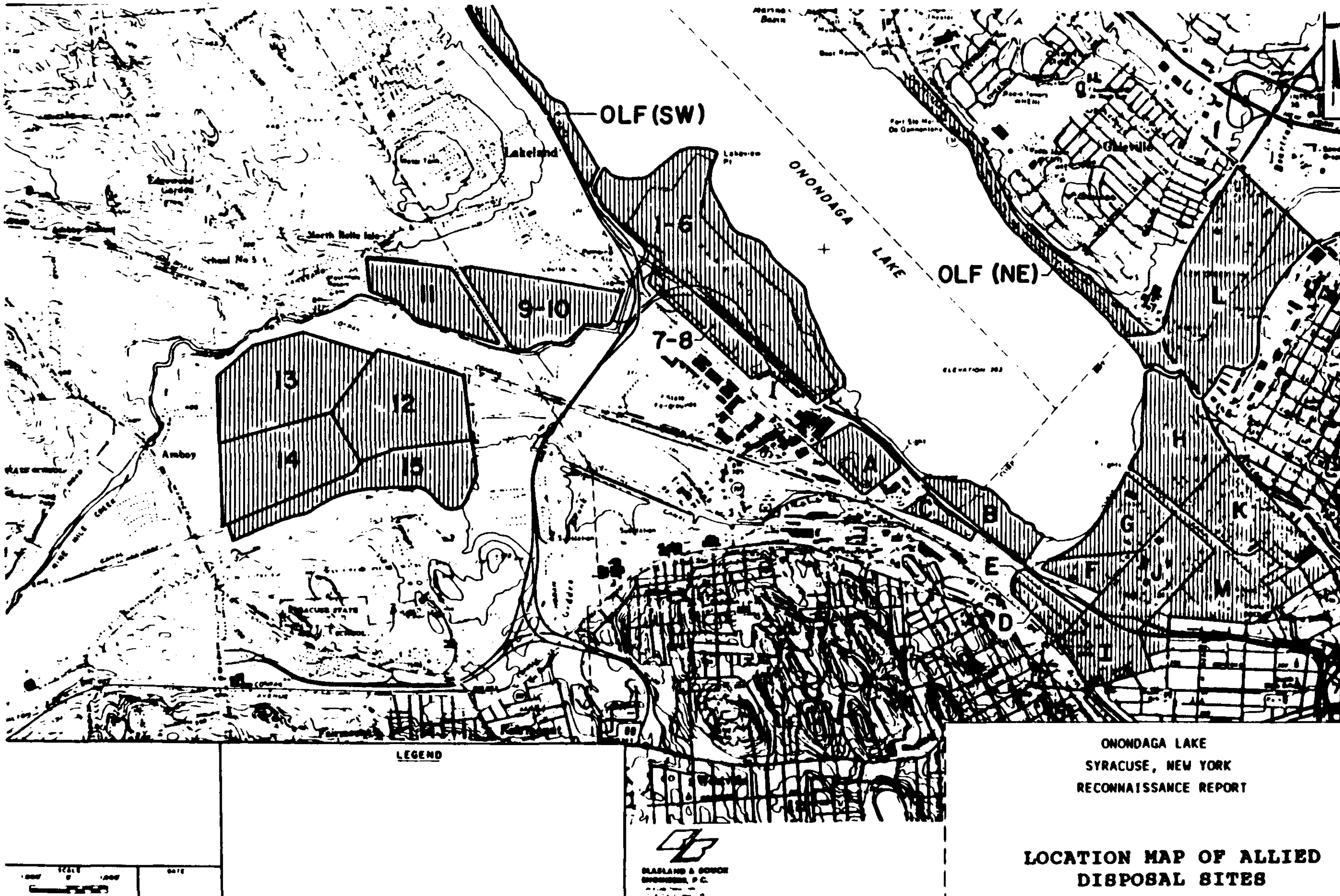
The results of the surface water sampling indicate that the concentration of chlorides, calcium, and sodium increase in Nine Mile Creek as it flows toward Onondaga Lake. Results from the 1987 surface water monitoring indicate that upstream of the waste beds the chloride loading concentration is 47 mg/l and downstream of State Fair Boulevard the concentration is 1200 mg/l. The groundwater sampling showed an increase in the concentration of chlorides, calcium, and sodium as the depth in Nine Mile Creek Valley increased.

The Willis Avenue site contains benzene, toluene, xylene, naphthalene, and chlorobenzenes, and the contaminants have been found in the groundwater.

The Clark Property is the site of a former concrete and asphalt operation located just south of Onondaga Lake. The site was a major oil storage facility but it is now an inactive hazardous waste site, including the presence of solvent contamination.

The Quanta site is a former oil reprocessing plant which has been out of business since 1980. The contaminants which are stored in tanks are waste oils, sulfuric acid, and PCB's.

The Maestri site was used by Stauffer Chemical for the disposal of 70-90 drums. The groundwater is contaminated with xylene.

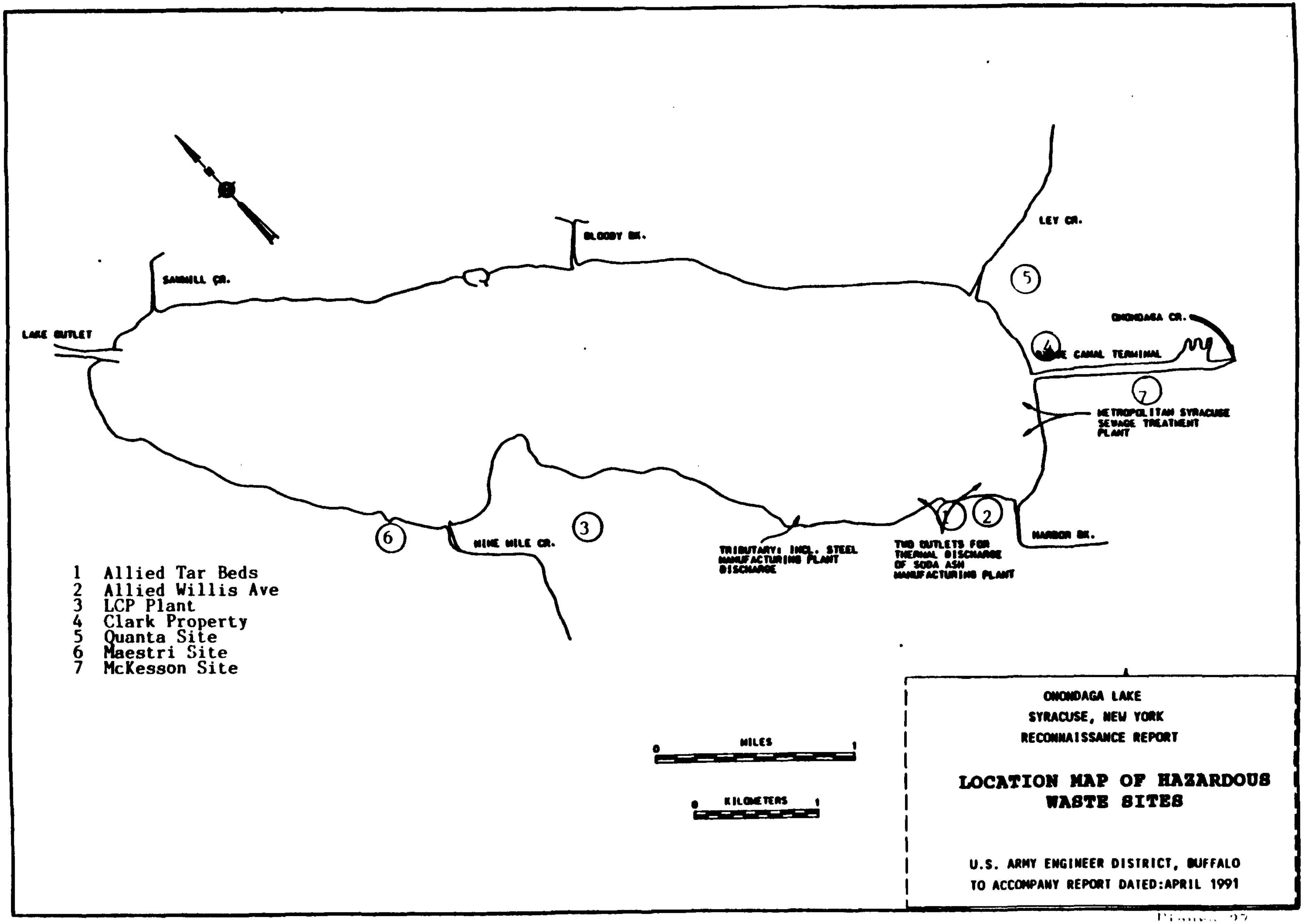


ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

LOCATION MAP OF ALLIED DISPOSAL SITES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 2b



LEY CR.
BLOODY BK.
SAWMILL CR.
LAKE OUTLET
ONONDAGA CR.
CANAL TERMINAL
METROPOLITAN SYRACUSE SEWAGE TREATMENT PLANT
HARBOR BK.
TWO OUTLETS FOR THERMAL DISCHARGE OF SODA ASH MANUFACTURING PLANT
TRIBUTARY: INCL. STEEL MANUFACTURING PLANT DISCHARGE
NINE MILE CR.
1 Allied Tar Beds
2 Allied Willis Ave
3 LCP Plant
4 Clark Property
5 Quanta Site
6 Maestri Site
7 McKesson Site
MILES
0
1
KILOMETERS
0
1
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT
LOCATION MAP OF HAZARDOUS WASTE SITES
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 27

The McKesson site contains numerous storage tanks that were used for the storage of bulk petroleum products and waste solvents. Although some remedial cleanup has been completed, some remaining contaminated soil and groundwater is present at the site.

Oil City is an area of Syracuse where nine major oil terminals are presently located. Over the years various spills or leaks have occurred and created plumes of dissolved product and pure product.

The DOT Barge Canal terminal and maintenance area are located where Onondaga Creek flows into the southern end of Onondaga Lake. The area has been a repository for dredged spoils. Available data indicates the sediments are high in oil and grease, but not hazardous.

Upstream from the mouth of Ley Creek along the banks is located the disposal site for dredged sediment from Ley Creek. Remedial investigation for this area is underway.

3.1.6 Non Point Sources

The nonpoint sources of pollution will gain more attention as the major point sources of pollution are brought under control. The 1987 amendments to the Federal Clean Water Act focused increased attention and priority on the development and implementation of nonpoint source control programs.

The Water Quality Act of 1987 focused increased attention and priority on the development and implementation of nonpoint source control programs. Section 319 of the Act required states to prepare an Assessment Report identifying waterbodies affected by nonpoint source pollution, determining categories of nonpoint sources that are significant problems in the state and listing state programs available for the control of nonpoint source pollution. States were also required to prepare a Management Program which explained how they planned to deal with the source categories causing the major problems.

The Department of Environmental Conservation (DEC) produced these documents for New York. The Assessment Report was approved by EPA in July 1989 and the Management Program was approved in January 1990. The Assessment was based on DEC's existing database of water quality problems. Throughout the process of preparing the Assessment Report, it was recognized that the list contained in the Report could not be regarded as a complete and final inventory of segments adversely affected by non-point source pollution.

In early 1989, a process was established to enhance DEC's list of segments having water quality problems. Among the goals of this assessment was to use additional data sources to identify possible nonpoint source impacts, to provide an opportunity for everyone with a knowledge of water quality problems to present this information and to expand the list to include segments that are threatened by non-point source pollution.

The Department of Environmental Conservation, working in conjunction with the State Soil and Water Conservation Committee, initiated a two phased approach to identify problem waterbodies. The first phase had each Soil and Water Conservation District conduct a survey of nonpoint source pollution in their county. Districts invited agencies, groups and individuals from within the county to participate in identifying water quality problems. Districts collected information and presented it to DEC during the next phase of the process.

The second phase consisted of meetings of representatives from the key agencies within each county to discuss the results of the NPS survey. The meeting provided the Soil and Water Conservation District personnel and DEC Regional Water and Fisheries staff with an opportunity to discuss water quality problems in each county. When there was a consensus that a water quality problem existed on a specific waterbody, information regarding the problem was recorded.

Recognition of a water quality problem was the starting point for discussions. The existence of a land use which may be associated with nonpoint source pollution was not sufficient to be considered a problem. A classified use of a surface waterbody or groundwater must be precluded, impaired, stressed, or threatened to be regarded as a problem.

A procedure for verification of information presented during the first two phases was then initiated. Only segments with verified water quality problems are included on the Division of Water's Priority Water Problem (PWP) list.

Verification of nonpoint source related water quality problems was done by DEC Regional Offices, DEC Central Office or another agency under the guidance of DEC. The water quality impacts were verified in several ways. These included the analysis of existing data, the documentation of use impacts (water supply shutdowns, beach closings, etc.), the use of biological or visual indicators (fishery survey, weed harvesting program results) and the conduct of a water quality sampling program.

Segments for which it has been confirmed that a problem exists will be added to the PWP list. Other segments which were nominated were dropped because verification procedures demonstrated that no problem or threat to water quality exists.

The report cited the sources of nonpoint pollutants. They are, in order of significance, atmospheric deposition, on-site wastewater systems, diffuse urban runoff and agricultural activities.

The assessment for Onondaga County listed 26 segments including several tributaries to Onondaga Lake. Affected uses included fishing, fish propagation, fish survival, bathing, and aesthetics.

The preliminary work done by DEC requires verification of the water quality problems. Once the problems are verified, a detailed study of the watershed will be required to determine the relative contributions of sources present.

A major source of sediment and dissolved salts known as the mud boils has been identified in the Onondaga Creek watershed in Tully Valley. The source has been isolated to an area where sediment is introduced to the surface water through the groundwater. It affects the transparency in the lake and has caused sediment deposits in Onondaga Creek.

Various studies of the Tully Valley area, which include determining the cause of the mud boils, have been underway by the New York State Attorney General's Office and NYSDEC. Most of the information regarding this site is confidential pending litigation.

The mud boils are surface features located in the Tully Valley approximately 18 miles south of Syracuse. They are cone shaped structures which range in diameter from less than 1 meter to 5 meters and are usually less than .6 meter in height; however, some are as high as 1 meter.

These features are apparently subsidence-related and are comprised of sand, silt, and clay brought to the surface by artesian pressure (Getchell, 1978). They are formed by the discharge of confined groundwater flowing through unconsolidated deposits, when the natural stress exceeds the effective stress of material comprising the aquifer and overlying aquitard. Weaknesses in the overlying impermeable material allow the effusion of liquefied sediment to the surface, discharging as a slurry of sediment and water. The sediment may settle out around the cone or it is carried downstream to Onondaga Creek. The slurry is produced as water erodes the unconsolidated material lining as it flows through.

The discharge is also apparently dependent on the pressure head of the artesian supply. The pressure head is high following spring thaw or heavy rainstorms and at those times the sediment concentration is higher (Getchell, 1978). Apparently the discharge and sediment input to Onondaga Creek have increased through time as more mud boils have formed.

A preliminary analysis conducted by Getchell (1978), shows the relative impact of sediment carried to Onondaga Creek from a tributary with its headwaters at the mud boils. Measurements that were taken on 21 May 1981, resulted in the following: 1) at 183 meters upstream from the mud boils, in the tributary draining the subsidence area, suspended sediment concentration was 43 mg/l; 2) at 30.5 meters upstream from the tributary's confluence with Onondaga Creek, and 122 meters downstream from the ejection features, the suspended sediment concentration was 1970 mg/l; and 3) at 30.5 meters downstream from Otisco Road the amount of suspended sediment concentration was 151 mg/l.

A field survey was conducted in the fall of 1988 by UFI in which flows and sediment concentration were measured in Onondaga Creek and the tributary to Onondaga Creek adjacent to the mud boils (Effler, Johnson, Jiao, and Perkins, 1989). Results of their study showed that the concentrations upstream of the mud boils in Onondaga Creek and in other tributaries were low compared to concentrations observed immediately below the mud boil on all occasions.

The (Effler et al, 1989) study also found the concentration of suspended solids in Onondaga Creek just below the mud boils was between 100 and 125 mg/l for all three surveys. Concentrations of from 760 to 860 mg/l were measured in small tributaries (located 33 km upstream of the lake) that carried portions of the "mud boil" discharge to Onondaga Creek during surveys. According to estimates made by Dr. David Johnson of SUNY at Syracuse, the sediment discharge is between 1/2 and 5 tons per day. NYSDEC estimates a possible 38 tons per day sediment discharge during the high recharge spring period. Based on more recent sampling by USGS sediment concentrations range from 11,000 to 13,000 mg/l and flows of 0.4 CFS from the mudboils.

Recently Buffalo District personnel collected samples of the sediment-water mixture that was discharged from the mud boils during a site visit in June 1990. The samples were taken as grab samples at one point in the tributary just downstream of the main mudboil area. The flow at the time of sampling was relatively low. The samples were sent to the laboratory for the following analysis; settling velocity, chloride concentration, and particle

size. The Column Settling Test procedure involved placing the water/sediment sample into a large glass cylinder, mixing vigorously and then allowing the sediment to settle. The sediment/water interface and suspended solids content above the interface were measured until the suspended solids concentrations from all four ports were the same for two sample periods. The cylinder utilized for performance of the settling test was constructed of Pyrex glass and measured 60 inches tall with an inside diameter of 7 inches.

Four glass ports with 5/8 inch ID's were located at 12, 24, 36 and 48 inches from the bottom of the cylinder. Hydrometer testing in accordance with ASTM Method D 422-63 constituted the Particle Size Analysis for the sample. An aliquot of sample was washed through a #200 sieve to verify that a Particle Size Analysis by method CRL-485 (sieve testing) was not required. The purpose of the sampling and testing program was to determine sediment characteristics that are necessary to design a settling basin, which could be a possible pollution abatement alternative.

Results of the column settling tests are summarized on Table 7. The data show that most of sediment settles out of solution within 2 hours. The results of the particle size analysis are shown on Table 8. The sediment concentration of the sample collected was 3,800 mg/liter. The chloride concentration of that sample was 880 mg/liter. NYSDEC has recorded chloride concentrations 3 to 6 times greater than this value.

The water quality of Onondaga Creek and its ability to serve as a fishery and a fish-spawning area as well as Onondaga Lake's transparency have been impacted by the additional sediment that is deposited from the mud boils. Further analysis regarding the process that causes the mud boils and the relation to subsidence is currently underway by the NYSDEC and the Attorney General's Office. Based upon results from NYSDEC, they estimated that the mud boil effluent contains 25 to 75 percent sediment before it mixes with the small tributary to Onondaga Creek.

Table 7 Column Settling Test "Mud Boil" Area
Suspended Solids Results (mg/l)
(Based on a loading of 3.8 gm/l)

Sample Number	Elapsed Time (hrs)	Interface Height (inches)	Water Surface (inches)	Port 1 (48")	Port 2 (36")	Port 3 (24")	Port 4 (12")
1	0	55.06	55.06	3820	3850	3880	3800
2	2	0.88	54.88	86	--	--	--
3	4	1.50	54.75	45	49	74	--
4	8	1.25	54.25	15	20	27	24
5	24	0.88	53.25	10	6	4	6
6	48	0.75	52.50	2	<1	<1	2
7	96	0.75	51.63	1	4	3	6

Table 8 Hydrometer Analysis of Sediment From "Mud Boil" Area

Percent Finer	Particle Diameter (mm)	
100	0.04	coarse silt
7.6	0.039874	coarse silt
6.76	0.02776	medium silt
5.91	0.014304	medium silt
5.07	0.010214	medium silt
2.53	0.007292	fine silt
2.53	0.003646	clay
2.53	0.001488	clay

Additional information on the mud boils is presented in Section 5.5.

3.1.7 Sediments

The in-place lake sediments also provide a source of pollutants by recycling or retaining the various contaminants within the system. The pollutants that are associated with the sediments include phosphorus, nitrogen, mercury, PCB's, heavy metals, and sulfides.

Internal phosphorus has been identified as impacting the water column phosphorus concentrations. The release rate from the sediments is governed by the rate of phosphorus deposition from the overlying water and the oxygen concentration in the overlying water. As the external loads of phosphorus are reduced, the release rate can be expected to decrease. In a study by Auer and Johnson, 1989, phosphorus release rates were measured on intact cores. Results of the analysis indicate that the mean phosphorus release rate is 13 mg $P \cdot m^{-2} \cdot d^{-1}$. The internal loads are the second largest for Onondaga Lake, contributing 29 percent of the overall phosphorus load.

Mercury, PCB's, and other heavy metals are present in the sediments and have been found in fish flesh (Sloan et al 1987; Spagnoli and Skinner, 1977; Young, Depinto, and Seger, 1982). Sediment cores were obtained at various sites in Onondaga Lake to analyze the concentration of mercury (Rowell, 1990). Results shown in Figure 28, indicate that the concentration is higher in the north basin than the south. The Section 5.3.1, entitled Dredging, shows figures delineating sediments containing mercury with various concentrations of mercury.

3.2 Loads

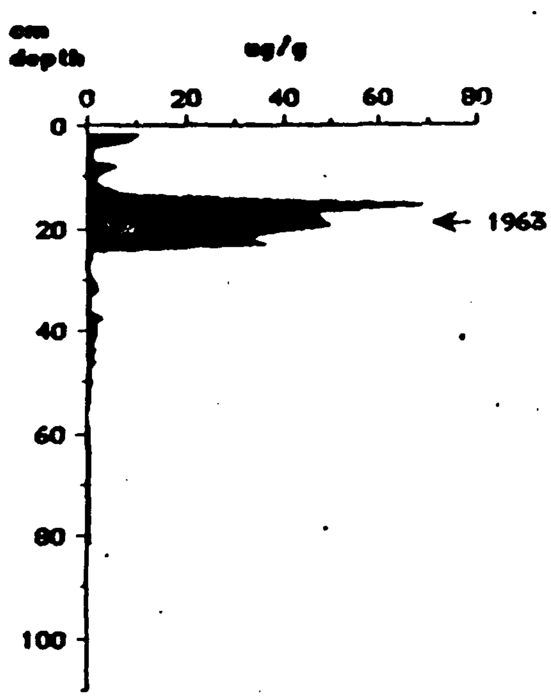
3.2.1 Nutrients

3.2.1.1 Phosphorus

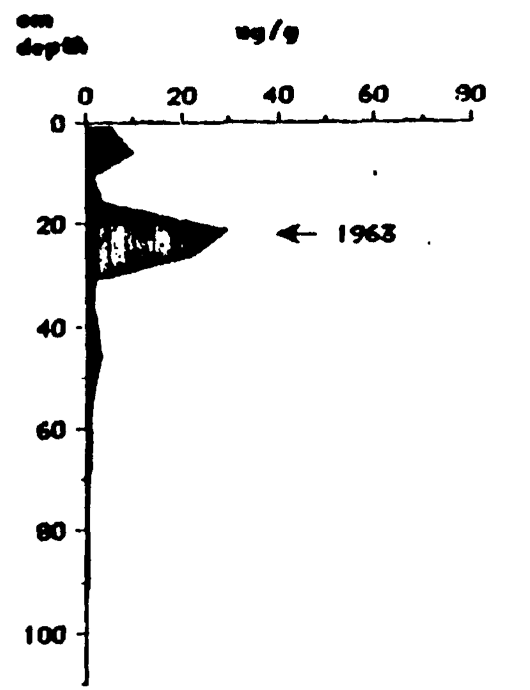
The relationship between phosphorus inputs and in-lake phosphorus concentration have been analyzed extensively due to the impact that it has on water quality. The phosphorus inputs are currently high enough to support extensive levels of algal production.

The phosphorus sources have been classified as either external or internal. External sources deliver "new" phosphorus to the lake from point sources or non-point sources. Internal loads constitute the biogeochemical cycling of phosphorus within the lake (Auer and Johnson, 1989).

Hg in North Basin (Core 35)



Hg in South Basin (Core 22)



Rowell, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CONCENTRATION OF Hg IN TWO SEDIMENT CORES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 28

Based upon earlier studies, it was determined that retention of the high phosphorus loading to Onondaga Lake in the sediments is partially attributed to the high concentrations of calcium that have been contributed to the lake by the industrial activities (Effler, 1984). The response of the lake to changes in phosphorus loading is very rapid because the lake's rate of flushing is 2.6 to 5.2 times per year (Devan and Effler, 1984).

A total phosphorus monitoring program was performed by Upstate Freshwater Institute between 16 June and 22 August 1987. The purpose of the study was to determine the average daily load for each of the 10 tributary sources using paired flow and concentration measurements. Results of the analysis shown on Figure 29 indicate that METRO is the largest source of total phosphorus contributing 292 lbs/day or 84 percent of the total external loading during this two month summer period. Onondaga Creek was the next largest, yielding 24 lbs/day or 7 percent, and Nine Mile Creek contributed 15 lbs/day or 4 percent.

Summary Table 9 shows the loads from 1969 through 1975 compared to more recent years. The total quantities have been drastically reduced. A Vollenweider Plot of the total phosphorus (Figure 30) shows that the loads to Onondaga Lake are still approximately 65 times greater than the loads which would be necessary to establish a mesotrophic lake.

Table 9 Comparison of Total Phosphorus Loads

Year	Load (lbs/d)	Load (kg/d)	Mass Rate of Accumulation ($gP.m^{-2}y^{-1}$)	Reference
1969	10948	4966	155	Murphy, 1978
1970	12800	5806	181	Murphy, 1978
1971	2697	1223	38	Murphy, 1978
1972	2803	1271	40	Murphy, 1978
1973	2057	933	29	Murphy, 1978
1974	2949	1338	42	Murphy, 1978
1975	1454	660	21	Murphy, 1978
1987	777	352	11	Heidtke,1989
1988	639	290	9	Stearns & Wheler 1989
1989	584	265	8	Stearns & Wheler 1990

Note that the 1987 loads (Heidtke, 1989) are for only a summer period

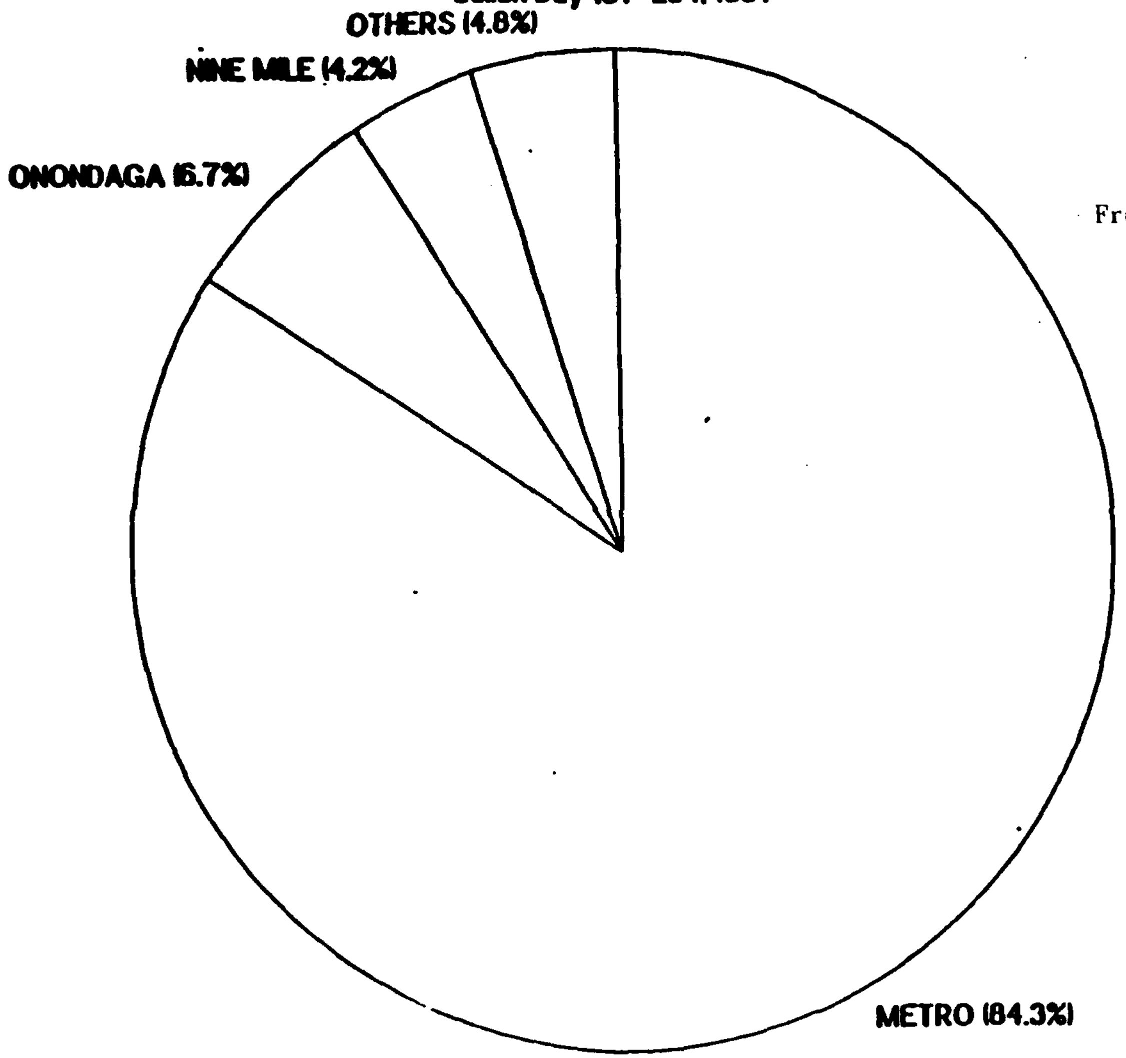
3.2.1.2 Nitrogen

Total nitrogen is actually the sum of ammonia, nitrate, and nitrite and organic nitrogen. The largest component of the inorganic nitrogen has been identified previously as ammonia. The primary sources of total ammonia are inputs from the watershed and the decomposition of organic material in the lake. These sources result in elevated levels of ammonia in the hypolimnion and the epilmnion.

The 1988 monitoring program performed by Onondaga County Department of Drainage and Sanitation showed that the concentrations of ammonia in the lake were above the NYSDEC chronic toxicity standards on more than 80 percent of the sampling days in the epilimnion and the hypolimnion. These violations of

ONONDAGA LAKE TOTAL PHOSPHORUS LOADS

Julian Day 167-234, 1987



From: Upstate Freshwater Institute

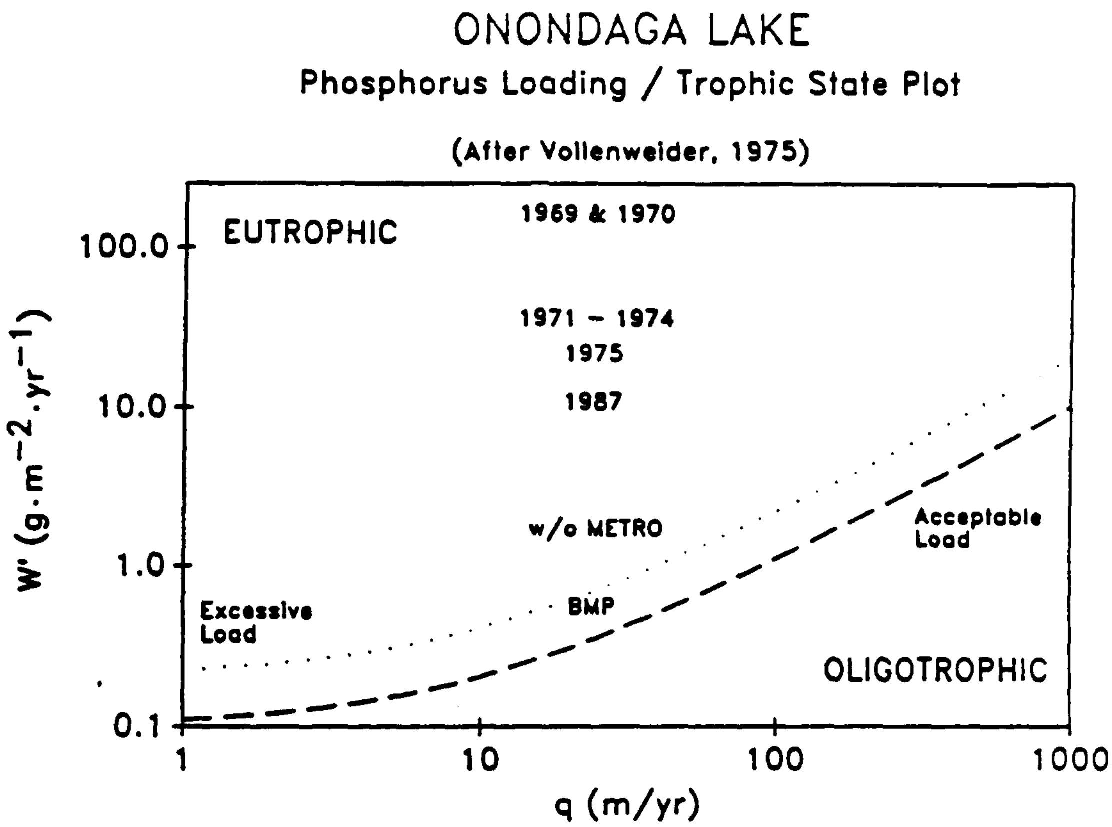
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TOTAL PHOSPHORUS LOADS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 29

Figure 29



From: Upstate Freshwater Institute, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

PHOSPHORUS LOADING/ TROPHIC STATE PLOT

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 30

chronic toxicity standards for ammonia persist from spring through fall. The sediments are a major source of ammonia N to the hypolimnion during stratification.

The sum of average mass loading rates of nitrogen to Onondaga Lake for 1988 and 1989 are shown below on Table 10. The METRO discharge was responsible for 89.4 percent of the external ammonia load in 1988.

Table 10 Average Mass Loading Rates of Nitrogen for 1988 and 1989

	1988	1989	Percent Change
NH_3-N	10,500 lbs/day	7,630 lbs/day	-27.3%
NO_3^-N	3,060 lbs/day	4,550 lbs/day	48.7%
NO_2^-N	613 lbs/day	452 lbs/day	-26.3%

From Stearns and Wheler, 1990

3.2.2 Ionic Salts

The ionic salts that are contributed to Onondaga Lake have been greatly reduced because Allied-Signal Inc. was closed in 1986. The 1987 data showed approximately a 70 percent decline in the average concentrations of calcium, sodium, and chloride (Stearns and Wheler, 1989).

The results of the 1989 monitoring data show that Nine Mile Creek continues to be the largest contributor of ionic salts to the lake. Onondaga Creek is the second highest contributor with METRO being the third largest source.

The sum of the average mass loading rates for 1988 and 1989 from each input source to the lake for calcium, sodium and chloride are shown below on Table 11. For comparison, the 1984 results are included to show the magnitude of the reduction that occurred after the closure of Allied-Signal.

Table 11 Sum of the Average Mass Loading Rates for 1988 and 1989 for Calcium, Sodium, and Chloride (lbs/day)

	Pre Allied Closure 1984	1988	1989
Chloride	5,210,000	955,000	1,010,000
Sodium	1,310,000	406,000	439,000
Calcium	1,570,000	387,000	459,000

From Stearns and Wheler, 1985 and 1990

3.2.3 Heavy Metals

The discharge of heavy metals has been reduced over the years with the improved regulations and technology. The loading of iron, chromium, and copper from Crucible Steel was reduced in 1974 when they built a water treatment and reuse system. Linden Chemicals and Plastics (LCP) shut down their mercury cell chlor-alkali process in 1988 after discharges of mercury and chlorine above permit levels were documented.

The 1989 monitoring data from the county show that METRO contributes the greatest quantities of lead, copper, chromium, and cadmium. Nine Mile Creek is the second highest contributor, and Onondaga Creek is the third. (Stearns and Wheler, 1990).

The sum of the average loading rates from each input source mentioned above, to the lake for the heavy metals is shown below:

	1987	1988	1989
Lead	44 lb/day	42 lb/day	41 lb/day
Copper	40 lb/day	36 lb/day	74 lb/day
Chromium	27 lb/day	23 lb/day	21 lb/day
Cadmium	10 lb/day	8 lb/day	9 lb/day

From Stearns and Wheler, 1990

3.2.4 Bacteria

The concentration of fecal coliform bacteria is used by the New York State Department of Health to determine whether water can be safely used for contact recreation. The current standard specifies that the logarithmic mean of five fecal coliform samples collected on successive days not exceed 200 colonies per 100 ml of water.

The monitoring program performed by Onondaga County has collected biweekly data since 1977. This type of data is not evidence of year-round compliance because it does not necessarily include storm data when concentrations are likely to be higher.

Results of the 1988 monitoring show that Onondaga Creek contributes the greatest percentage of fecal coliforms. Nine Mile Creek contributes the second largest amount, and Ley Creek is the third greatest contributor. Ley Creek contributes the most fecal strep. Onondaga Creek is the second largest contributor with METRO contributing the third largest amount.

4. CURRENT STUDIES

4.1 United States Environmental Protection Agency (USEPA)

The United States Environmental Protection Agency (USEPA) is not currently conducting an independent study on Onondaga Lake, however, they have been a source of funding for NYSDEC under the Clean Water Act Section 314 - Clean Lakes Program to both the Onondaga Lake Management Conference and the Onondaga Lake Water Quality Management Projects as well as the Construction Grants Program. They are also involved in several enforcement actions at hazardous waste sites around the lake.

4.2 New York State Department of Environmental Conservation (NYSDEC)

4.2.1 General

The New York State Department of Environmental Conservation (NYSDEC) has been actively involved with the increasing public interest in the clean-up of Onondaga Lake. The lake clean-up was a goal of the Governor's program articulated in the 1989 State of the State message. The NYSDEC followed up on Governor Cuomo's 1989 State of the State message by preparing an Onondaga Lake Strategy. The strategy reviewed the major problems of the lake and their

contributing causes, outlined the status of applicable NYSDEC programs and activities, and identified necessary future actions to address each of the various problems.

The major categories of program activities and/or areas of NYSDEC interest are: (1) those related to problems of mercury in the lake sediments and calcite deposition of the lake bottom; (2) those related to excessive salinity in the water; (3) those related to water quality problems which are associated with municipal sewage discharges, including the problems of bacteria, dissolved oxygen, transparency and ammonia toxicity; (4) those which address significant sites of in-place contamination (mostly listed as hazardous waste sites) adjacent to the lake or its tributaries; (5) those related to area-wide redevelopment of the "Oil City" area at the southern end of the lake; and (6) a general category of other activities in which NYSDEC has a strong interest.

The activities are described below including a brief summary.

4.2.2 Remedial Program Pursuant to New York State v. Allied Signal Inc. NDNY 89 CV 815.

New York State has asserted that Allied-Signal Inc. disposed of the waste products of its chemical manufacturing industry including hazardous substances, by dumping, spilling, and discharging such waste into Onondaga Lake and its tributaries and onto land areas which drain into Onondaga Lake.

The issues addressed in this litigation include mercury contamination of sediments and surface waters; and sodium chloride, calcium chloride, and calcium carbonate (calcites) contamination of sediments and surface waters, groundwater and soils.

Allied-Signal Inc. has been identified by NYS as responsible for the remediation of certain pollutants. A complaint was filed in the U.S. District Court on 27 June 1989 by the State of New York and Thomas C. Jorling as Trustee of the Natural Resources against Allied.

The State's complaint alleges that Allied is liable for all costs and expenses incurred and to be incurred by the State for the removal, remediation and response to contamination of Onondaga Lake for which they have been identified as responsible. In addition, the complaint alleges that Allied is liable for all damages to the natural resources of the State sustained as a result of the release of hazardous substances. Allied and the State are presently negotiating the provisions of a work plan for a remedial investigation and feasibility study that Allied would implement under State oversight.

4.2.3 Natural Resource Damages

New York State's Complaint 89CV815 against Allied also seeks to recover damages from Allied Signal, Inc. for injury to natural resources to be used for the restoration, rehabilitation and/or replacement of the injured resources including the costs of assessing the injury. This is pursuant to the NRD resolutions promulgated under CERCLA, 43 CFR Part II.

4.2.4 Fish Sampling Program (Mercury Trend Program)

Mercury was detected in Onondaga Lake fish in 1970 at high concentrations. The source of mercury was from the chloro-alkali process operated by Allied

Chemical where it was used as an anode in the production of chlorine from brine solutions. At the peak production, the waste mercury was discharged at a rate of approximately 21 pounds/day (9.55 kg/day).

Fishing was prohibited in 1970 due to the high mercury levels in fish. The average mercury concentration for three species of fish ranged from 1.6 to 5.8 parts per million (ppm). Smallmouth bass were included in the monitoring in 1972. Results of the monitoring indicated that the mercury levels declined through 1979. In 1980 and 1981, the levels rose again to levels found in 1974-76. The levels for smallmouth bass averaged 1.03 ppm total mercury (range 0.38-1.85 ppm) in 1984. The fishing ban was removed in 1986, however, the Department of Health recommends that the fish are not consumed.

The NYSDEC plans to continue to monitor changes in mercury concentrations in indicator fish species and to regulate human consumption through the health advisory process. In addition, the effectiveness of the remedial activities will be evaluated.

4.2.5 Allied Waste Beds Closure

Allied-Signal is responsible for producing over 1,000 acres of waste beds from their manufacturing processes over the past 100 years. These waste beds and the contaminated groundwater are the major source of ionic inputs to Nine Mile Creek and the lake. Allied signed a consent order with NYSDEC in February 1987 and agreed to perform a hydrogeologic assessment (completed April 1989) and a feasibility study of the waste beds and their impacts on surface and groundwaters.

The State's goals are to insure that remedial actions are properly implemented to close the beds and to achieve maximum feasible reduction of salt inputs to Nine Mile Creek and Onondaga Lake. In addition, the State will seek damages for impacts from the waste beds on the environment.

4.2.6 Water Quality Model Development

The water quality modeling has been underway since 1987 by the Upstate Freshwater Institute funded by NYSDEC and monies from settlement of the METRO lawsuit with Onondaga County. The discussion of the modeling efforts is summarized in Section 4.6, Upstate Freshwater Institute.

4.2.7 Non Point Sources

The nonpoint source loadings to Onondaga Lake include those other than the METRO treatment plant and its associated combined sewer overflows. Presently these source loadings are less significant than METRO and the combined sewer overflows. However, as the point source loadings are reduced in the future, the nonpoint will become more significant.

Onondaga County and NYSDEC prepared a proposal for a Federal Clean Lakes Program Diagnostic-Feasibility Study in 1989 to investigate non point sources of sediment and submitted it to USEPA for funding consideration. The project was not funded by USEPA but the diagnostic element is being carried out by the Onondaga Lake Management Conference.

The purpose of analyzing the non point sources is to define the loads for use in modeling. The models will be used to support control decisions for METRO and CSOs. In addition, a non point source management program will be developed.

4.2.8 Sludge Disposal

The Onondaga County municipal treatment plant sludge is currently dewatered at the Metro plant. Approximately 50% or 100 wet tons per day is being hauled to and disposed of at Modern Landfill in Niagara County. The remaining 50% or approximately 100 wet tons per day is being mixed with cement kiln dust and converted into N-Viro soil utilizing the N-Viro soil process. The N-Viro soil is being beneficially reused as a fertilizer and soil conditioner on agricultural land in central New York.

NYSDEC's objectives with respect to the sludge are to ensure that it is disposed of in an environmentally sound manner by meeting all necessary permits and requirements. They also will assist the county in developing re-uses of sludge in accordance with the State solid waste management plan.

4.2.9 Inactive Hazardous Waste Sites

Various sites have been identified around Onondaga Lake as hazardous waste sites and were shown in Figure 27. A brief summary as of this writing is provided below:

The main purpose of the hazardous waste remediation is to eliminate hazardous waste at each of the designated sites and to eliminate the migration of the hazardous constituents. Other potential environmental impacts of the sites such as surface runoff and volitization of contaminants will also be determined.

4.2.9.1 Allied Tar Beds

A 22-acre site on the southwestern side of Onondaga Lake was used by Allied from 1917-1970 for disposal of wastes. The groundwater investigations have shown the presence of contaminants including benzene, toluene, and napthalene. A consent order was signed between Allied and NYSDEC requiring completion of a Remedial Investigation/Feasibility Study. The Remedial Investigation work was initiated in November of 1990.

4.2.9.2 Allied Willis Avenue

The Willis Avenue site is the location of a former chlorobenzene manufacturing facility. A consent order was developed between Allied and NYSDEC. A work plan for the Remedial Investigation is under development. The objectives are to eliminate the migration of contaminants in the groundwater including benzene, toluene, xylene, napthalene, and chlorobenzenes into the lake.

4.2.9.3 LCP Plant Site

The LCP (Hanlin Group) facility manufactured chlorine utilizing the "mercury cell." The facility was closed down in 1989 when allegations were made that they had violated their wastewater permit. The site now has mercury contaminated soil and groundwater, and there is speculation that it may be migrating to the lake. Remediation of the site will be pursued through a RCRA Corrective Action.

4.2.9.4 Clark Property

The Clark Property is the site of a former concrete and asphalt operation and is located south of Onondaga Lake. A portion of the site has been classified as an inactive hazardous waste site due to the presence of solvent contamination. The site has been the subject of interim remedial measures. Remedial Investigation has been approved and the Feasibility Study is to be submitted shortly.

4.2.9.5 Quanta

This site is a former oil reprocessing plant which has been out of business since 1980. Many tanks on the property contain waste oils and some caustics which include sulfuric acid and PCB's. Some of the tanks show visible leakage and deterioration. Because the site is located upgradient from Onondaga Lake, there is a potential for the migration of contaminants via groundwater to the lake, however, the presence of groundwater contamination has not been determined. The site is presently the subject of removal action by USEPA.

4.2.9.6 Maestri

The Maestri site is located in a residential-commercial area upgradient of Onondaga Lake. It is a highly vegetated vacant lot which was used in the 1970's for disposal of approximately 70-90 drums of chemicals from Stauffer Chemical Company. Groundwater sampling indicates that xylene is present downgradient of the site. A consent order was signed between ICI Americas Inc. (purchaser of Stauffer Chemical) and NYSDEC in October 1988 which require site investigation and implementation of interim remedial measures. Additional buried drums were discovered during the interim remedial field work.

4.2.9.7 McKesson

The McKesson site occupies approximately eight acres in the center of the Oil City area. The site contained numerous storage tanks and was used for the storage of bulk petroleum products and waste solvents. A consent order was agreed upon previously, and the remedial investigation is nearly complete. Some contaminated soil and groundwater remain at the site.

4.2.9.8 Major Oil Storage Facilities Groundwater Contamination Investigation and Remediations

The southeastern end of Onondaga Lake where it is bisected by Onondaga Creek has been historically used for the storage of petroleum products. It has been proposed that these facilities be moved to a location away from Onondaga Lake. There are groundwater contamination problems that resulted from over 60 years of petroleum terminal operations in the area.

NYSDEC will seek to have the oil companies define the contamination which exists and do remedial work that will eliminate substantial impacts on Onondaga Lake, Onondaga Creek and any other receptors. The initial sampling and groundwater elevation survey around the 10 terminals is completed.

4.2.9.9 DOT Canal Maintenance Area

The DOT Barge Canal terminal and maintenance area is located where Onondaga Creek flows into the southern end of Onondaga Lake. The area is used

for DOT dredges and other maintenance vessels. DOT has dredged Onondaga Creek through the terminal area to maintain passage for its fleet. Dredged spoils areas are located along the west bank of the creek. NYSDEC has some data on the sediment chemical quality. More investigation may be needed before the spoils are distributed.

The DOT canal terminal is being considered for a harbor area which will include public access.

The NYSDEC's objectives for this site are to assure that the dredge spoils from the area are properly evaluated and disposed of. Any additional contamination problems identified during the redevelopment will be properly addressed. In addition, boat launching facilities for public access are being considered for the redevelopment.

4.3 New York State Attorney General's Office

The New York State Attorney General's office has brought an action in U.S. District Court against Allied Signal Corporation alleging, inter alia, natural resources damages and violations of the "Superfund" statute (CERCLA). The defendant is presently negotiating with the New York State Department of Law, the parameters of a workplan for a remedial investigation to be conducted by the defendant's consultant to address the toxic deposits, in particular mercury, in the lake sediments.

In addition, the Attorney General's Office is investigating the problem in Tully Valley with the mud boils.

4.4 Onondaga County Department of Drainage and Sanitation

4.4.1 General

One of the major contributors of pollutant loadings to Onondaga Lake is the Onondaga County Metropolitan Sewage Treatment Plant, its collection system, and associated combined sewer overflows. The objective of the current studies and projects by the Onondaga County Department of Drainage and Sanitation (OCDDS) is the reduction of pollutant discharges into Onondaga Lake and its tributaries pursuant to United States District Court for the Northern District of New York Judgment on Consent 88-CV-0066, dated 31 January 1989. The Court Order directs OCDDS and Onondaga County to complete planning, design, and construction activities necessary to bring all violations of sewage discharge to Onondaga Lake and its tributaries into compliance. The achievement of discharge compliance is expected to lead to Onondaga Lake water quality improvement and the attainment of a fishable and swimmable lake. The control alternatives to achieve compliance are to be evaluated through a series of water quality models currently under development by the Upstate Freshwater Institute (UFI), as described in Section 4.6 below. Upon completion of the model evaluation, a Municipal Compliance Plan (MCP) will be developed by Onondaga County that will include a schedule for implementation of the pollutant reduction alternatives which provide for the attainment of ambient water quality criteria based on protection of the "best usage" of Onondaga Lake and its effected tributaries.

4.4.2 Ley Creek and Liverpool Pump Stations

Serious impacts to Onondaga Lake have resulted from wastewater bypasses occurring at both the Liverpool and Ley Creek Pump Stations as well as overflows occurring at various points throughout their service area's sewer

system. Due primarily to the excessive flow in the system, the lack of capacity of both pump stations, and lack of capacity in the Ley Creek interceptor continuous dry and wet weather discharges are bypassed into tributaries impacting the nearby Lake. These violations were noted by the NYSDEC Regional Office and incorporated into the Syracuse METRO permit for correction. Improvement projects were subsequently funded under the last phases of the Construction Grants program and are now under construction.

The completion of both projects to eliminate the discharge violations was also incorporated as a requirement of the 1989 judicial order issued against Onondaga County.

Through the elimination of the bypasses at both pump stations and further reduction of overflows in the system, the projects will contribute to the overall efforts to reduce bacterial contamination of Onondaga Lake and should also provide some reduction of the wet weather loadings of nutrients and biochemical oxygen demand. The Liverpool project is scheduled for completion in May 1991 and Ley Creek is scheduled for November 1991. The additional flow that will be discharged to METRO may cause further exacerbation of the overloading problems already apparent.

4.4.3 Metropolitan Wastewater Treatment Plant

The objective of current studies at the wastewater treatment plant is to develop pollutant reduction alternatives to bring all violations of sewage discharge to Onondaga Lake into compliance with the consent order of 31 January 1989. Following is a list of tasks included in the workplan for the management alternatives:

4.4.3.1 Develop Current Plant Performance Characteristics

This establishes existing plant influent flows and pollutant loadings as well as flows and pollutant loadings discharged to Onondaga Lake via the main plant outfall and the partially treated wet weather discharge. The database presented will be used to select appropriate METRO STP effluent loadings for input to the water quality models being developed for Onondaga Lake by Upstate Freshwater Institute (UFI) (Stearns and Wheler, July 1990).

4.4.3.2 Evaluate the Impact of Extraneous Flow Abatement Program

Investigations concluded that implementation of an extraneous flow abatement program to eliminate improper roof drain, sump pump, and footing drain connections to separate sanitary sewers will primarily impact the METRO STP by reducing the frequency, duration, and magnitude of stormwater bypass occurrences. Based on analysis of metered flow data for January 1986 through May 1990, elimination of <u>all</u> improper roof drain, sump pump, and footing drain connections would be projected to reduce the peak METRO STP influent flow from 242 MGD to 221 MGD (8.7%) and reduce the maximum monthly average influent flow from 104 MGD to 97 MGD (6.7%). The magnitude of flow reduction, therefore, is relatively minor in comparison with the total flows influent to the METRO STP (Stearns & Wheler, July 1990).

4.4.3.3 Evaluate Impact of Ley Creek and Liverpool Pump Station Upgrading

Available information will be reviewed and analyzed to determine the anticipated impact of these projects on flows and pollutant loadings discharged to Onondaga Lake via the main and stormwater outfalls from the METRO STP. Alternatives will be developed to handle any adverse impacts, such

that final effluent limits will be met. As of this writing, laboratory results of sampling data necessary to quantify pollutant loadings associated with sanitary sewage overflows at Ley Creek and Liverpool Pump Stations were incomplete.

4.4.3.4 Evaluate impacts of CSO Pollutant Reduction Alternatives

The impacts of CSO pollutant reduction alternatives on the performance of the METRO STP will be evaluated. Alternatives will be developed to handle any adverse impacts caused by CSO abatement, such that final effluent limits will be met.

4.4.3.5 Evaluate Impact of Upgrading and/or Expansion of Ley Creek STP

An investigation of the potential impact of reconstruction of the Ley Creek sewage treatment plant on influent sewage flows and loadings to the Metro STP was conducted. It was determined that a program of routine sampling and analysis of the Ley Creek sewage flow should be initiated in order to develop a more substantial data base from which to establish design sewage loadings. Removal of the Ley Creek sewage flow from the Metro STP plant influent can be expected to result in a significant reduction of sewage flow and loadings which may, in turn, offer a cost-effective solution to upgrading of the Metro STP due to severe site constraints imposed by the Metro plant site (Stearns & Wheler, September 1990).

4.4.3.6 Determine Performance Characteristics for Phosphorus Removal Alternatives

Projected effluent phosphorus concentrations tailored to water quality concerns were determined for various chemical and biological phosphorus removal alternatives based on lab-scale, pilot-scale, and full-scale case studies reported in the engineering literature (Stearns & Wheler, September 1990).

Chemical phosphorus removal alternatives which were investigated include precipitation of phosphorus in primary, secondary, and/or tertiary treatment systems using ferric chloride, ferrous chloride, ferrous sulfate, alum, sodium aluminate, or lime. Biological phosphorus removal alternatives which were investigated include the Phostrip process, the Bardenpho process (Barnard-Denitrification Phosphorus Process), the A/O process (a proprietary process marketed by Air Products and Chemicals Inc), and the VIP process (Virginia Initiative Plant Process). In addition, the impact of effluent filtration on both chemical and biological phosphorus removal was assessed (Stearns & Wheler, September 1990).

4.4.3.7 Determine Performance Characteristics for Ammonia Removal (Nitrification) Alternatives

Projected effluent TKN, ammonia nitrogen, and nitrate nitrogen concentrations tailored to water quality concerns were developed for ammonia removal (nitrification) alternatives based on a review of lab-scale, pilot-scale, and full scale case studies reported in the engineering literature. Ammonia removal alternatives which were investigated include biological nitrification using either a single-stage or two-stage activated sludge system (Stearns & Wheler, September 1990).

4.4.3.8 Determine Performance Characteristics for Nitrogen Removal (Denitrification) Alternatives

Projected effluent TKN, nitrite and nitrate nitrogen concentrations were developed for nitrogen removal (denitrification) alternatives based on a review of pilot-scale, and full-scale case studies reported in the engineering literature (Stearns & Wheler, October 1990).

4.4.3.9 Develop Effluent Discharge Alternatives

This task required an evaluation of effluent discharge alternatives for the METRO STP including: (1) continued discharge to Onondaga Lake via the existing nearshore outfall; (2) utilization of the existing deepwater outfall presently used for partially treated wet-weather stormwater flows; (3) construction of a new deepwater outfall; and (4) relocation of the discharge to the Seneca River.

4.4.3.10 Develop Flows and Pollutant Loadings to Ley Creek, Onondaga Lake, and Seneca River for METRO STP Management Alternatives

A matrix format will be developed for various combinations of pollutant reduction alternatives for METRO STP.

4.4.3.11 Develop Preliminary Design Information and Cost Estimates for Selected METRO STP Management Alternatives

These will be based on preliminary findings and conclusions of the water quality models.

A final report summarizing flows and pollutant loadings for the various alternatives investigated is scheduled for February 1991.

4.4.4 Combined Sewer Overflows

The objective of current studies related to the combined sewer overflows is to develop engineering alternatives for their treatment and/or diversion. The following is a list of the tasks included in the Workplan for the management alternatives:

4.4.4.1 Combined Sewer Overflow Flow Monitoring

This information was used to calibrate the collection system Storm Water Management Models (SWMM) and evaluate the reduction in CSO overflow volumes associated with the Best Management Practices (BMP) program implemented as a result of the 1979 CSO Abatement Program.

4.4.4.2 CSO Quality Monitoring

An analysis of Pre-BMP and Post-BMP data was conducted and results will serve as input to the water quality models being developed by UFI.

4.4.4.3 Develop SWMM Models of Existing Collection System

Collection models were developed for the Harbor Brook Interceptor, Main Interceptor, and Erie Boulevard In-System CSO storage. The model was calibrated based upon the CSOs monitored. This was done through the comparison of computer model generated CSO discharges to the measured discharges.

4.4.4.4 Develop Engineering Alternatives

Several state-of-the-art alternatives for CSO pollutant reduction were developed. These included: (1) separation of the collection system, (2) CSO transmission/centralized treatment including storage options, (3) CSO transmission/regional treatment, and (4) additional BMP measures.

4.4.4.5 Develop Loading Calculations for the Abatement Alternatives

Loads associated with the above alternatives were developed for different design storms. These loading rates will be used in the water quality models from UFI. Additional loading rate reduction estimates will be made for the Liverpool Pumping Station bypass and Ley Creek Service Area Improvements currently being implemented so that their influence can be evaluated through use of the Lake models.

Most of this work was completed by October of 1990.

4.4.5 Monitoring

The Onondaga County Department of Drainage and Sanitation (OCDDS) has sponsored an extensive annual monitoring program of Onondaga Lake and its tributaries since completion of a baseline study in 1971. The annual monitoring program is designed to assess the following:

a. Pollutant loadings to the lake from external sources.

b. Impacts of pollutant loadings on the lake ecosystem.

c. Changes in pollutant loadings to the lake over the years of study.

d. Trends in lake and tributary water quality.

e. Implications of changes in water quality on potential uses of the lake.

Technical input regarding the structure and conduct of the annual monitoring program have been provided since 1971 by an advisory committee of technical experts. The Onondaga Lake Technical Advisory Group helps maintain continuity in data collection and interpretation.

Each year, OCDDS contracts with an engineering/scientific consultant for assistance in interpreting the results of the annual monitoring effort. Recently the Syracuse-Onondaga County Planning Agency requested that an independent consultant provide a comprehensive validated data base of all the monitoring data from the county, the Department of Health, Upstate Freshwater Institute, and NYSDEC since 1970. A proposal to provide an independent review, and screen and synthesize the data was submitted by Walker, 1990.

4.5 Central New York Regional Planning and Development Board

The Central New York Regional Planning and Development Board was established in 1966 by a joint resolution of the Cayuga, Madison, Onondaga, and Oswego County Legislatures. It was organized under Article 12-B of the New York State General Municipal Law, which permits cities, towns, and/or villages in a county or counties of the State to establish a Regional Planning Board.

There are 38 voting members of the Board, representing all facets of the communities within the region. There are nine members for each of the four counties and two at-large minority members. This membership represents elected officials from the region's local governments, community leaders, business and industry interests, and members of minority groups.

The primary function of Regional Planning Organizations is to study the needs and conditions of an entire region, usually resulting in a Master Plan.

The Central New York Regional Planning and Development Board published a report in September 1989 entitled "Onondaga Lake Water Quality Management Project FY 1988." The report was financially aided through a New York State grant from the New York State Department of Environmental Conservation with funding provided by the U.S. Environmental Protection Agency. It was designed to be a 3-year program of which the 1988 report is the completion of the first phase. The purpose of the project was to identify the remaining scientific and technical investigative work required to complete the understanding of lake processes and subsequent impacts of pollutants entering the lake.

After that work is identified, the required remedial measures will be evaluated that would bring the water quality to acceptable standards. In addition, the project was intended to provide a clear overview of the necessary remaining research for management decisions.

The primary points that this report addresses: (1) the major lake studies that have been done to date; (2) current studies that are being done; and (3) remaining investigative studies that are needed as well as the purpose and the scope of the studies.

The September 1989 report is a summary of the first phase of the project. Included in the report is a compilation of the remaining technical study needs for the lake, the scope of work for each topic, and the purpose of each study. A summary of the current research is shown on Table 12. The topic areas that have been identified for additional analysis include sediment-water interactions, transparency, mercury, organics, groundwater, mud boils, biological aspects, lake/METRO/Seneca River, Nine Mile Creek/Onondaga Creek, and non-point source pollution.

4.6 Upstate Freshwater Institute

4.6.1 General

The Upstate Freshwater Institute (UFI) (a Not-For-Profit Research Corporation) has currently been responsible for the analyses of pollutant inputs and lake response through mathematical modeling. The development of these models has been funded jointly by Onondaga County (voluntarily under consent decree), New York State (Section 205 Clean Water Act funding through the NYSDEC), and the Federal Government (Section 106 Clean Water Act funding through the U.S. Environmental Protection Agency). The models address the following lake water quality issues: phytoplankton, phosphorus, ammonia nitrogen, fecal coliform bacteria, dissolved oxygen (DO), and transparency.

In addition to the modeling effort, UFI has also collected vast amounts of field data and performed laboratory analyses for various studies over the years. Details of analyses performed by UFI are presented above in Section 2 entitled CURRENT WATER QUALITY AND TRENDS. The modeling efforts are discussed below.

Table 12 Summary of Current Research Efforts on Onondaga Lake*

Project	Scope	Performed by	Completion Date
Ammonia Modeling	Model effect of ammonia inputs on concentration	UFI	1990
Ammonia Toxicity Assessment	Collect data to calibrate and verify model of ammonia toxicity	NYSDEC and OCDDS	Dec. 1988
Water Quality Planning Model	Demonstration o. water quality management applications	Engin Comp	Dec. 1988
Bacteria Modeling	Model effects of bacteria inputs on concentration	UFI	April 1989
CSO Abatement	Alternatives for collection, treatment and discharge of combined sewer overflows	Moffa & Assoc.	Sept 1990
Comprehensive Plant Evaluation	Review and analyze design and management to identify performance limiting factors and recommended changes	Stearns & Wheler	July 1990
Transparency Model	Influence of organic and inorganic particulates on Onondaga Lake clarity	UFI	1991
0 Degree of Freedom Phosphorus Model	Phosphorus input and concentration	UFI	1990
Oxygen Model	Effects of external and internal BOD load on dissolved oxygen in Onondaga Lake	UFI	1990 or early 1991
Lake Monitoring	Collection and analysis of data for substance loading to Onondaga Lake and the lake's responses	OCDDS	annually

* Based on Central New York Regional Development Board September 1989, updated CENCB-PE.

UFI - Upstate Freshwater Institute
OCDDS - Onondaga County Department of Drainage and Sanitation
NYSDEC - New York State Department of Environmental Conservation

4.6.2 Phytoplankton Model

The issue of how light, nutrients, and temperature affect the primary productivity in Onondaga Lake was the basis for the development of the phytoplankton model. The purpose of the model is to relate certain aspects of water quality, particularly oxygen and transparency, to changes in external phosphorus loading (Auer and Storey, 1989).

Specifically, the purpose of the phytoplankton model was to determine appropriate kinetic coefficients for algae growth and respiration rates. These rates are required in order to use accepted physiological models of phytoplankton growth. Actual phytoplankton assemblages from Onondaga Lake were used in combination with light and temperature simulations to verify the model. Because the phytoplankton community from the lake is phosphorus saturated, the Phosphorus Kinetic relationships were obtained from the literature (Auer and Storey, 1989).

The modeling results indicate that the growth rate coefficients and temperature and light effects are within the range reported in the literature. However, the coefficients for the respiration rate are higher than typical literature values. The results of the light and phosphorus simulation support the conclusion that the primary production by phytoplankton is limited by light (Auer and Storey, 1989).

4.6.3 Phosphorus Model

UFI has developed a phosphorus model. The purpose of the model is to predict the effect of changes in external phosphorus input on in-lake water quality. The relationship between phosphorus inputs and in-lake phosphorus concentrations must be considered as well as the relationship between in-lake phosphorus concentration and in-lake water quality. The model has the capability to assess the general relationship between lake assimilative capacity, phosphorus loading, and water quality to the specific conditions in Onondaga Lake. The model was designed with a "zero degree of freedom" which eliminates the need for calibration. The model will be used to analyze the projected changes in lake water quality under different scenarios of reductions in external phosphorus loads.

4.6.4 Ammonia Nitrogen Model

Ammonia nitrogen is a water quality parameter that is also being evaluated by modeling the Onondaga Lake and the Seneca River. The model primarily focuses on free ammonia toxicity and considers sources or sinks of ammonia as they impact the relationship between external nitrogen loading and in-lake ammonia concentrations. The Seneca River model focuses on dissolved oxygen and will describe the importance of bacterial nitrification to the river's oxygen budget. The Seneca River model was developed to evaluate the remediation alternative that would bypass the METRO discharge around the lake and into the Seneca River. Both models were developed using a mass balance approach and require specification of external and internal nitrogen loads, mass transport, and kinetic processes. For ammonia, the key kinetic mechanisms include algal uptake, ammoniafication, and bacterial nitrification.

The concentrations of ammonia are an important consideration in defining lake restoration alternatives. The appropriateness of the lake's water quality standards must be addressed, and the aquatic species and species assemblages must be defined.

4.6.5 Fecal Coliform Bacterial Model

The fecal coliform bacteria model was developed to describe the bacteria loadings under wet and dry weather conditions using the data base collected in 1987. This data base includes results from monitoring 10 tributary stations and 10 lake stations each weekday during the summer of 1987. The model also describes how different areas of the lake are affected by the bacteria inputs (using the lake circulation model and the kinetic dieoff and settling rate). The model also can predict how quickly the lake recovers from bacteria loads. This is done in conjunction with the lake circulation model and the kinetic dieoff and settling rates.

The fecal coliform model has been used, and results show an excellent agreement between predicted and observed lake water quality.

4.6.6 Dissolved Oxygen

The dissolved oxygen model will be developed to assess the effects of external and internal BOD load on dissolved oxygen in Onondaga Lake. The model is scheduled to be completed in late 1991.

4.6.7 Transparency

The transparency model will be developed to determine the influence of organic and inorganic particulates on Onondaga Lake clarity. It is scheduled to be completed by 1991.

4.7 Management Conference

The Onondaga Lake Management Conference is a group with six members. The members include the Assistant Secretary of Army for Civil Works, the Administrator of the U.S. Environmental Protection Agency, the Governor of New York State, the Attorney General of New York State, the County Executive from Onondaga County, and the Mayor of the city of Syracuse. Legislation was proposed by Senator Daniel Moynihan that would create the Management Conference and provide $100 million for implementing a clean-up plan. The legislation has not yet passed. By Congressional authorization, $500,000 for the initial activities of the Management Conference was appropriated.

The purpose of the conference shall be to recommend a management plan that identifies corrective action and compliance schedules for water quality remediation of the lake. It will also monitor the remedial measures and provide funding for special studies.

A technical review committee has been created within the Management Conference. The committee has developed goals summarized below.

(1) To review all past and current special studies and monitoring activities.

(2) To identify data gaps and needed analytical work to properly quantify and analyze lake processes, lake problems and issues, tributaries problems and issues relating to meeting water quality standards, and providing a physical setting to provide for fishable and swimmable waters.

(3) To delineate and prioritize those subjects and areas needing further study and analysis.

(4) Prepare appropriate budgets for studies and analytical work for submission to the conference and to the appropriate Federal, State, and local agencies.

(5) Solicit proposals to execute the needed work, review and select the desirable proposals, and recommend contracts to do the work.

(6) Develop remediation plans through various government agencies.

(7) Solicit specific engineering and scientific proposals to accomplish goals to meet water quality standards.

(8) Prepare an annual budget.

A citizens advisory committee has also been created within the Management Conference. The Committee has developed goals and objectives which are summarized below.

(1) The aesthetic qualities of the surface water and shoreline of Onondaga Lake shall be enhanced and improved.

(2) Onondaga Lake shall be made fit for human contact recreation from the mouth of Onondaga Creek to the Seneca River outlet.

(3) The wildlife habitat of Onondaga Lake shall be restored and enhanced to sustain a thriving ecosystem in the lower tributaries of Onondaga Lake and the lake itself.

(4) Any water quality remediation of Onondaga Lake shall not result in an adverse impact to the Seneca and Oswego River systems.

(5) The remediation of Onondaga Lake shall ultimately allow consumption of fish from the lake.

4.8 Oswego River Citizens Advisory Committee

The Oswego Harbor Remedial Action Plan was prepared by the New York State Department of Environmental Conservation in cooperation with the Oswego River Citizens Advisory Committee. The purpose of the study was to develop a strategy to correct environmental problems in the Oswego River and Harbor area of concern. The Remedial Action Plan is a three stage process. Stage I describes the environmental problems and impaired uses of the area of concern, the pollutants causing the impairments of uses and the sources of those pollutants. State II describes the remedial strategy, makes recommendations for remedial work, and describes methods for monitoring progress in remediating the areas of concern. Stage III is prepared when the beneficial uses of the area of concern have been restored, as shown by the monitoring results. At that time, a Stage III Remedial Action Plan is to be submitted to the International Joint Commission. In the Great Lakes drainage basin, the International Joint Commission (IJC) has identified 43 areas of concern where pollutants are impairing beneficial uses of a water body. Onondaga Lake has been identified as a significant source to the Oswego River Area of Concern. Based upon the Stage I report, Onondaga Lake was identified as a source of phosphorus and mercury, and is suspected as a possible source of PCB's.

4.9 Syracuse-Onondaga County Planning Agency

The Syracuse-Onondaga County Planning Agency requested that an independent consultant review, screen, and synthesize the lake and tributary data that have been collected over the years by the Onondaga County Department of Drainage and Sanitation, the Department of Health, and the Upstate Freshwater Institute. The proposal was prepared by Walker, 1990. Six tasks were identified to complete the Scope of Work. They are: (1) identify potential data uses, (2) prioritize water quality parameters, (3) compile data bases, (4) conduct preliminary data analysis, (5) screen data base, and (6) analyze and interpret the data base.

5 MANAGEMENT ALTERNATIVES AND COSTS

5.1 METRO STP

5.1.1 Phosphorus Removal Alternatives

In accordance with a condition of the Consent Order Settlement between Onondaga County and the NYSDEC, a full-scale chemical testing program is currently being performed at the METRO STP. Testing of phosphorus removal by chemical precipitation using iron salts was performed during the period of May 1989 through June 1990. Monthly average phosphorus removals ranged from 80.5 to 89.1 percent with average effluent total phosphorus concentrations ranging from 0.46 to 0.88 mg/l. This performance data is considered typical for phosphorus removal by chemical precipitation using iron salts.

Lime addition systems for phosphorus precipitation are characterized as either low-lime or high-lime processes depending on the amount of lime added. This reaction is independent of phosphorus concentrations but is a function of pH, as the solubility of the calcium phosphate precipitate varies with pH.

In low-lime addition, the pH of the wastewater is kept below 10. Because of the solubility of the calcium phosphate precipitate, low-lime phosphorus removal is generally limited to an optimum of 80 percent phosphorus removal, with a minimum effluent total phosphorus concentration of 1.0 mg/l. However, if a high alkalinity wastewater is treated by the low-lime process, quite often excellent phosphorus removals are achieved with the pH in the 9.5-10 range. This is due to alternate reactions between lime and the alkalinity which result in increased calcium phosphate precipitate formation.

In general, the low-lime process is typically used in primary treatment to eliminate the need for recarbonation. When phosphorus removal is performed by chemical precipitation using lime in primary treatment, BOD and suspended solids removals are also increased, resulting in decreased loadings to secondary treatment. Formation of magnesium hydroxide precipitate having poor settling characteristics can be avoided by keeping the pH in the low-lime range.

In high-lime addition, the pH of the wastewater is raised to 11.0-11.5 to achieve very high phosphorus removals. Effluent from a two-stage lime process followed by filtration can achieve an effluent total phosphorus concentration of approximately 0.1 mg/l. Effluent filtration is often required because at high pH, lime reacts with any magnesium hardness in water, forming a gelatinous magnesium hydroxide precipitate with poor settling characteristics.

High-lime addition to primary treatment results in great quantities of sludge with a higher quantity of solids than that from low-lime addition. Tertiary sludges from high-lime addition are very similar to sludges produced from water softening.

When high-lime addition is used, recarbonation is required to lower the pH for subsequent biological treatment of effluent discharge. (Stearns and Wheler. Sep 1990)

5.1.2 Nitrification Alternatives

Although the METRO STP was not designed for ammonia removal, it has been capable of achieving some degree of biological nitrification, particularly during warm weather conditions. TKN removal efficiencies through the METRO STP have ranged from 25 to 50 percent during cold weather conditions and from 50 to 85 percent during warm weather conditions. Effluent ammonia - nitrogen concentrations have typically ranged between 10 and 20 mg/l on a monthly average basis during the months of November through May. However, during the months of June through October, effluent ammonia - nitrogen concentrations have ranged from 2 to 10 mg/l, indicating the occurrence of biological nitrification (Stearns and Wheler, 1990). Given the current plant influent flows and loadings and the design conditions of the METRO plant, this is probably the limit of biological nitrification that can be expected to occur. For consistent nitrification, major plant modifications will be necessary.

Based on the analysis, it is projected that upgrading of the METRO STP for ammonia removal using a single-stage activated sludge system would be capable of achieving the following performance characteristics based on proper design and operation:

	Maximum Month	Peak Week
CBOD5	21 mg/l	31.5 mg/l
Suspended Solids	30 mg/l	45.0 mg/l
TKN	5 mg/l	--
Ammonia (as N)	2 mg/l	--

Performance characteristics for carbonaceous BOD and suspended solids presented above are based on current "interim" effluent limitations established by the NYSDEC for the METRO STP discharge. These interim limits in the court decree have been established as something METRO could meet in its present shape. Adjustment of concentration limits and mass loading in the discharge for these parameters will be made after runs are made on the water quality models for Onondaga Lake and the Three Rivers System. These performance characteristics represent projected effluent concentrations selected on the basis of current METRO performance data and typical performance data for full-scale and pilot-scale studies reported in the engineering literature.

Upgrading of the METRO plant for year-round nitrification, however, would require larger facilities and significantly greater cost than upgrading for seasonal nitrification only. (Stearns and Wheler, Sep 1990)

5.1.3 Nitrogen Removal Alternatives

The denitrification processes reviewed have proven to be effective in removing nitrogen from wastewaters. However, the most successful operations have been demonstrated in warmer climates. Considering the local climate, it is projected that upgrading of the METRO STP for nitrogen removal would be capable of achieving an effluent total nitrogen concentration of 10 mg/l or less, depending on the alternative used and assuming proper design and operation. Table 13 presents projected maximum monthly average effluent

concentrations for three groups of alternatives: three- and two-sludge denitrification systems; single-sludge denitrification systems; and post-denitrification filters. Effluent concentrations for BOD and suspended solids in Table 13 for all of the alternatives are based on current "interim" effluent limitations established by the NYSDEC for the METRO STP discharges as stated previously. Adjustment of concentration limits and mass loadings in the discharge for these parameters will be made after the water quality runs are made for Onondaga Lake and Three Rivers. Post-denitrification filters will produce lower effluent concentrations of BOD and suspended solids because they also filter the effluent. The alternatives that utilize methanol as the carbon source for the denitrification reaction (three-and two-sludge denitrification systems and post-denitrification systems) can obtain lower effluent nitrate concentrations than systems that do not utilize methanol. Post-denitrification filters will produce the lowest effluent concentrations of total nitrogen because they utilize effluent filtration and addition of methanol. (Stearns and Wheler, Oct 1990)

Table 13 Projected Maximum - Monthly Effluent Concentrations for Denitrification Measures

Parameter (mg/l)	Three- and Two-Sludge Denitrification Systems (1)	Single-Sludge Denitrification Systems (1)(2)	Post-Denitrification Filters
CBOD(3)	21	21	15
TSS(3)	30	30	15
TKN	5	5	4
Ammonia as N	2	2	2
Nitrate as N	3	5	3
Total N	8	10	7

1) Assumes no effluent filtration.
2) Includes Bardenpho, A2/O, VIP and Cyclical Aeration denitrification systems.
3) Based on current "interim" effluent limitations established by the NYSDEC for the METRO STP discharge. These limits were not meant to dictate final design parameters. An engineering determination of these parameters should be made.

SOURCE: Stearns and Wheler, October 1990

5.1.4 Effluent Discharge Alternatives

Evaluation of the alternative involving discharge of treated effluent from the METRO STP to the Seneca River has not been performed to date. This work will require input from the updated Three Rivers Model which is presently being prepared by Upstate Freshwater Institute (UFI) under contract to the Central New York Regional Planning and Development Board. Utilization of the

Three Rivers Model will be necessary to determine the level of treatment necessary for direct discharge to the Seneca River. Once the level of treatment is determined, evaluation of the engineering alternatives will be completed by Stearns and Wheler.

During wet weather conditions when sewage flows exceed the capacity of secondary and tertiary treatment (120 mgd), chlorinated primary effluent is discharged to Onondaga Lake via a 60-inch diameter stormwater outfall pipeline. The pipeline is approximately 1,785 feet in length and discharges at a depth of approximately 20 feet below the mean surface level of the lake. The depth of discharge is approximately at the boundary of the epilimnion and hypolimnion of the lake. The hydraulic capacity of the pipeline has been calculated at approximately 95 mgd under mean lake level conditions. Under maximum lake level conditions the capacity is reduced to approximately 45 mgd. As a result, the existing deepwater outfall does not have adequate capacity for the peak flow of 120 mgd through secondary and tertiary treatment. Flows exceeding these values would be relieved to a 60-inch nearshore outfall pipeline via an overflow weir in the existing stormwater junction box.

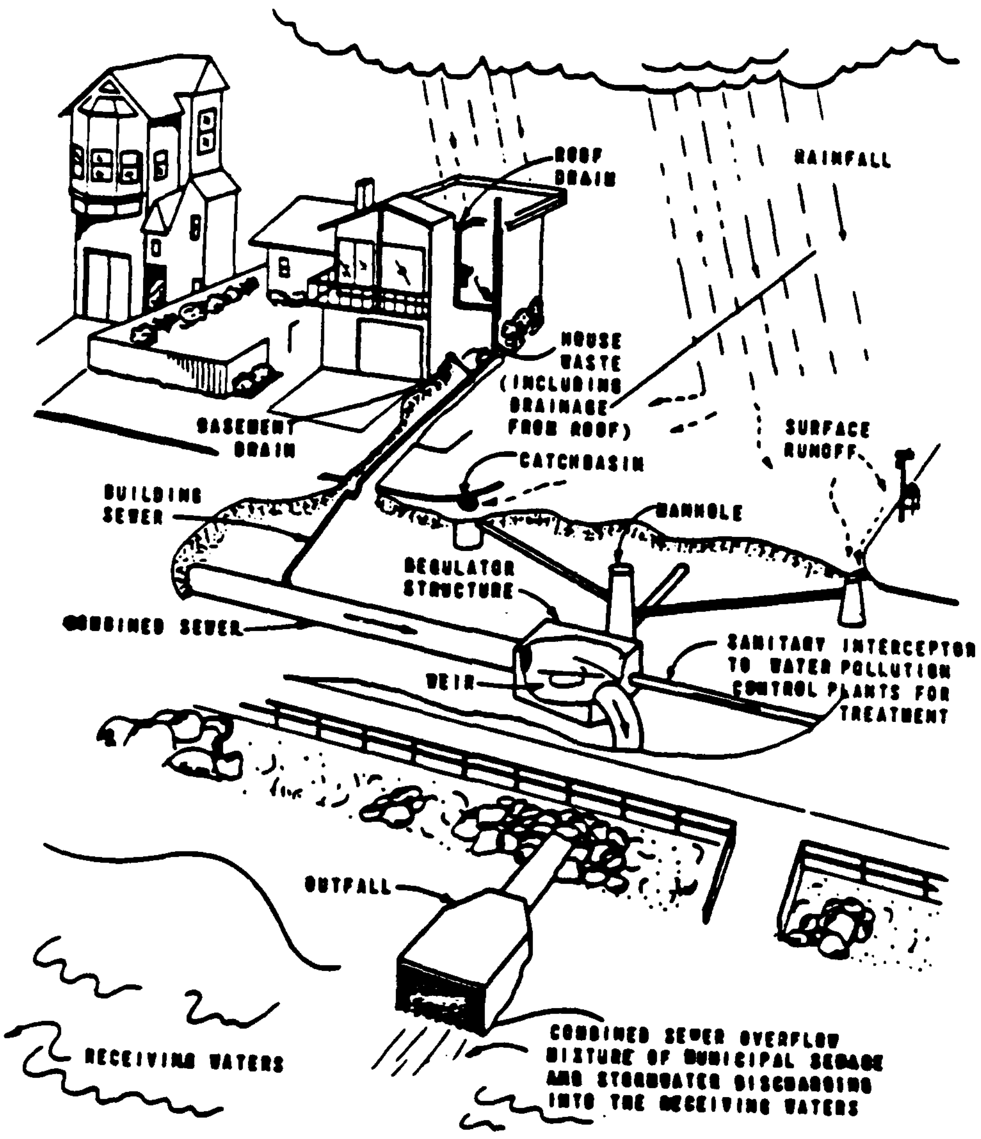
Deep water discharge of the entire 120 mgd peak sewage flow at a depth of 20 feet would require extension of the existing 96-inch diameter outfall pipeline for a distance of approximately 1,800 feet into Onondaga Lake. An outfall diffuser would likely be necessary to reduce the buoyancy of the discharge due to differences in physical and chemical characteristics. The diffuser design would be dependent on the allowable mixing zone for the plant effluent. To date, however, lake water quality modeling efforts have not defined an allowable mixing zone for the METRO effluent. (Stearns and Wheler, Nov 1990). It must be noted that the 96" shoreline discharge was justified based on the high ionic content of the METRO discharge when it included all of the wastebed overflow. The heavy METRO discharge would dive, maximizing mixing and diffusion. This basis may no longer be appropriate since Allied is not operating.

5.2 CSO Treatment and/or Diversion

The Combined Sewer Overflow Facilities Plan Update was completed in February 1991 by Moffa and Associates for the Onondaga County Department of Drainage and Sanitation. Some of the alternatives that were investigated were ultimately dictated through the Consent Order for the METRO STP and incorporated into the work plan. These alternatives are discussed in the following sections.

5.2.1 Separation of Combined Sewer System

Figure 31 shows a typical combined sewer system. Sewer separation refers to the conversion of the single combined sewer system into two separate systems, a sanitary and a storm. Separation of domestic sewage and industrial wastewaters from stormwater would be accomplished by constructing a new sanitary sewer system and using the existing combined sewer system for stormwater. Sanitary laterals would have to be separated from the existing storm system and reconnected to the new sanitary system. Stormwater would also have to be separated from the sanitary wastewater within each structure. This would eliminate combined sewer overflows and all sanitary flow would be



From: United States Environmental Protection Agency, 1974

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TYPICAL COMBINED SEWER SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 31

treated prior to discharge to Onondaga Lake. This alternative would be extremely disruptive since it would require the excavation of trenches and installation of sanitary sewers in every street in Syracuse presently served by combined sewers. The process would not eliminate pollution since urban area stormwater runoff contaminants would still pass untreated to the receiving waters.

However, separation does seem to be a viable solution for small and remote CSO basins (less than 20 acres). It is particularly applicable where construction of stream crossings would be necessary to connect an overflow to a centralized or regionalized CSO interceptor pipeline. Estimates show that the breakoff point for inclusion of small CSO drainage basins in regional or centralized abatement schemes is approximately 20 acres. For areas smaller than that, the net cost to construct an inverted siphon is greater than the cost of basin separation (Moffa & Associates, 1991).

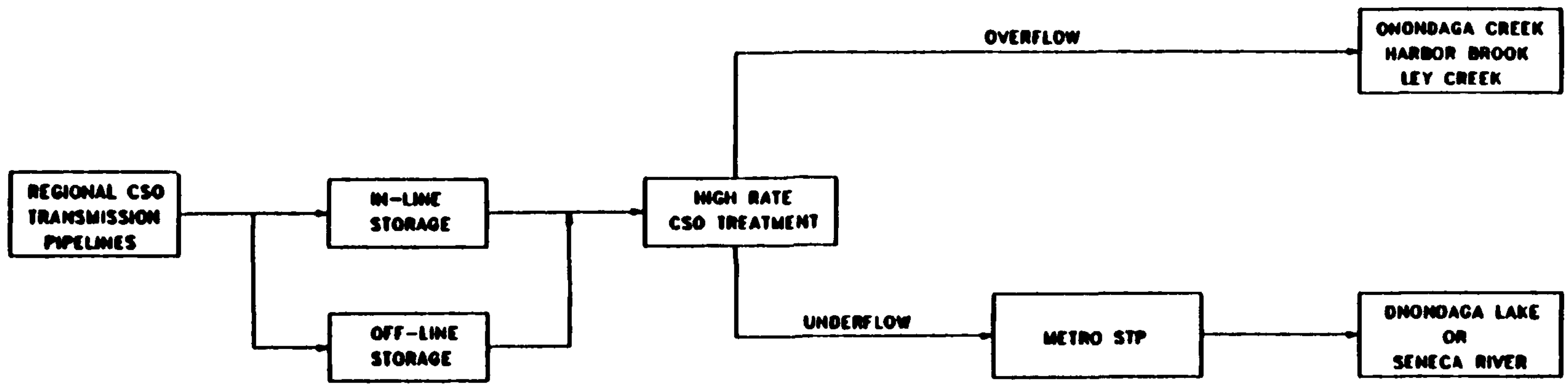
In general, other alternatives are much less expensive and could give better results with respect to receiving water pollution abatement. The estimated project cost for complete sewer separation is approximately $550,000,000 (O'Brien & Gere, 1979).

5.2.2 Regionalized Collection/Treatment

The regionalized concept, as shown in Figure 32, requires the construction of CSO interceptor pipelines that lead to high rate treatment facilities. Treatment includes the removal of settleable solids and floatables in a swirl concentrator, as shown in Figure 33, followed by high rate disinfection. The 1979 Final Report (O'Brien & Gere, 1979) found that it was more economical to consolidate overflows within regional basins than to provide treatment for individual overflows. Preliminary Plans were developed as part of the 1979 Final Report to demonstrate the principal components of this alternative, including sewer profiles and general layout of treatment facilities. The general location of regionalized treatment facilities is shown on Figures 34 and 35 and the typical flow schematic is shown in Figure 36.

There are a total of ten regional facilities recommended for CSO abatement. Two of these are the existing Newell Street swirl facility (that would be upgraded) and the Maltbie Street Microscreening facility (that would be upgraded to a swirl concentrator facility). The swirl facilities were sized for a 90-percentile storm, the CSO transmission pipelines were sized for a larger 1-year storm, and the disinfection facilities were sized for the maximum conveyance capacity of the system. The logic behind this approach is that the treatment facilities could be readily upgraded to provide higher treatment rates if future water quality concerns dictated. The upgrading of pipe capacities necessary to increase the design capacity from a 90-percentile to a 1-year storm, however, would be more expensive and disruptive. Therefore, the transmission pipelines were sized for the 1-year storm.

The Environmental Protection Agency's Storm Water Management Model was the principal tool used to evaluate the adequacy of the originally recommended facilities. The procedure used in this analysis required the addition of proposed pipelines and junctions onto the calibrated model of the existing



From: Moffa & Associates, 1990

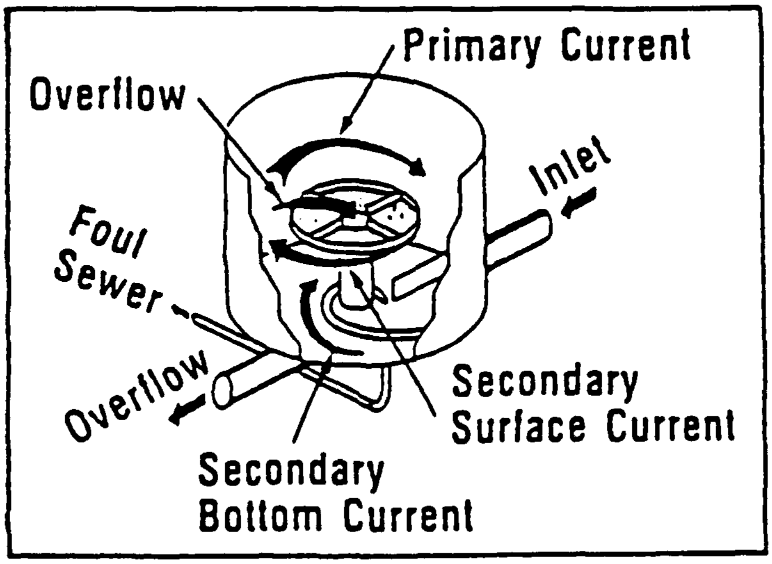
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

REGIONALIZED CSO TREATMENT CONCEPT

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 32

Figure 32



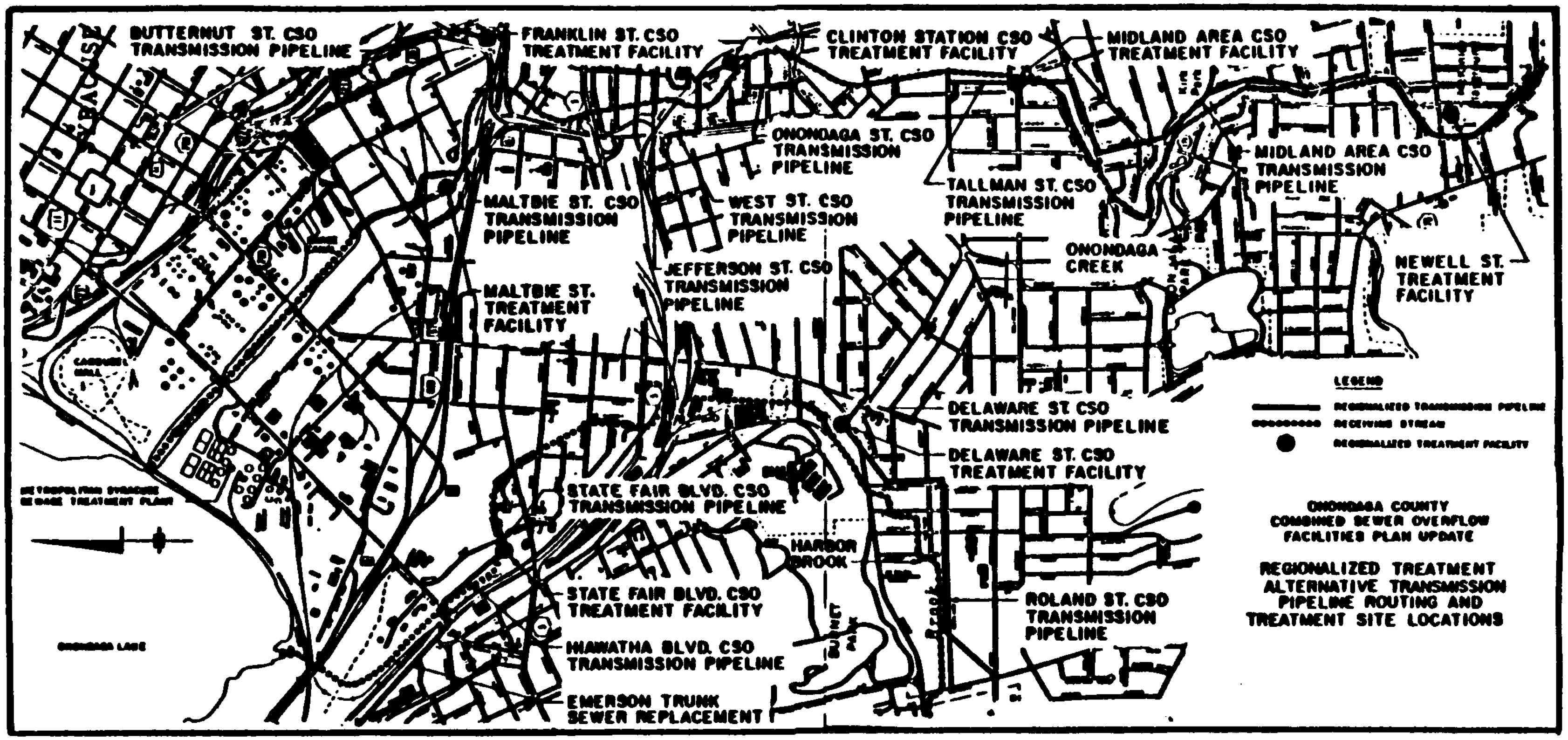
From: Moffa & Associates, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SWIRL CONCENTRATOR CONCEPT

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 33



From: Moffa & Associates, 1990

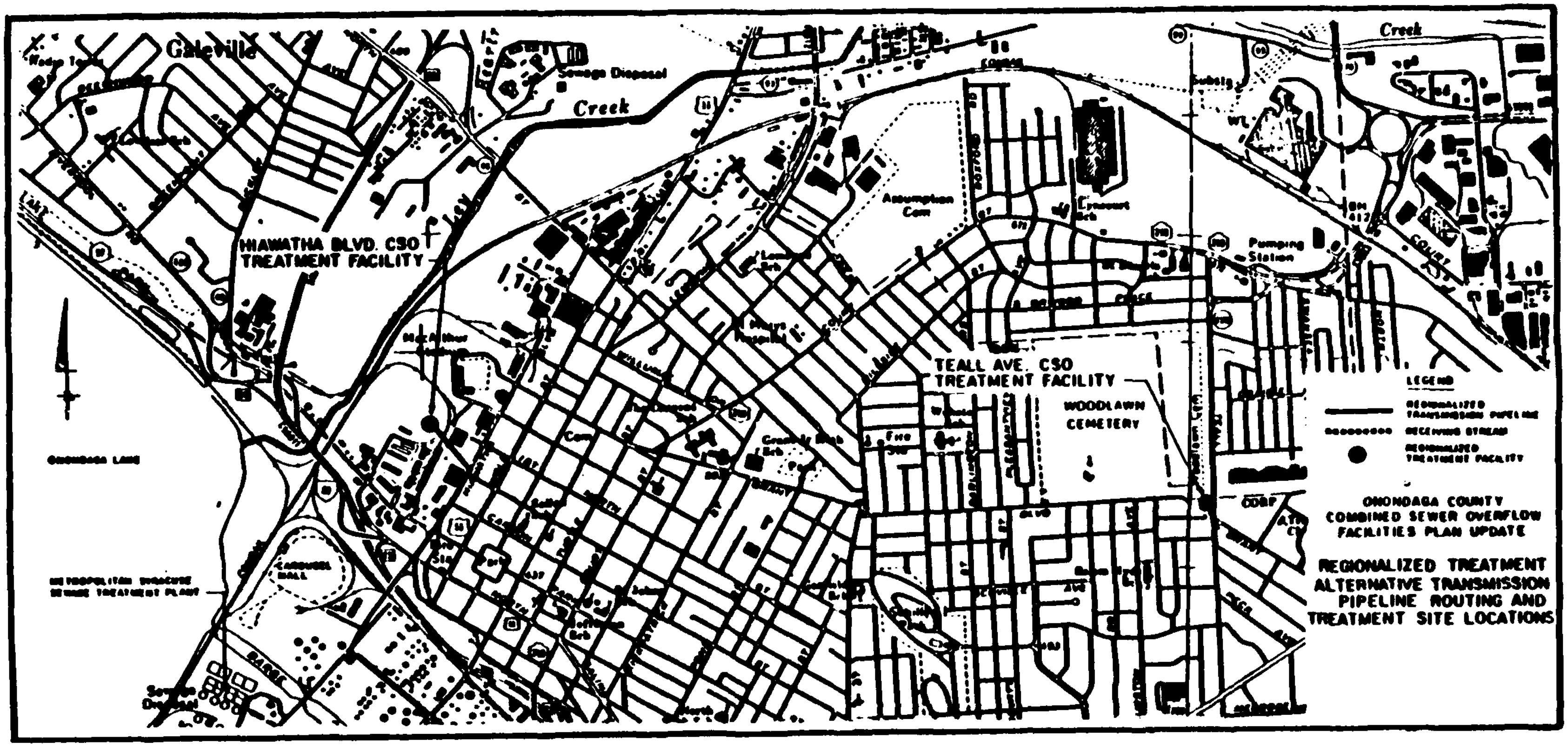
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

REGIONALIZED CSO TREATMENT SCHEME

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 34

Figure 34



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

REGIONALIZED CSO TREATMENT SCHEME LEY CREEK

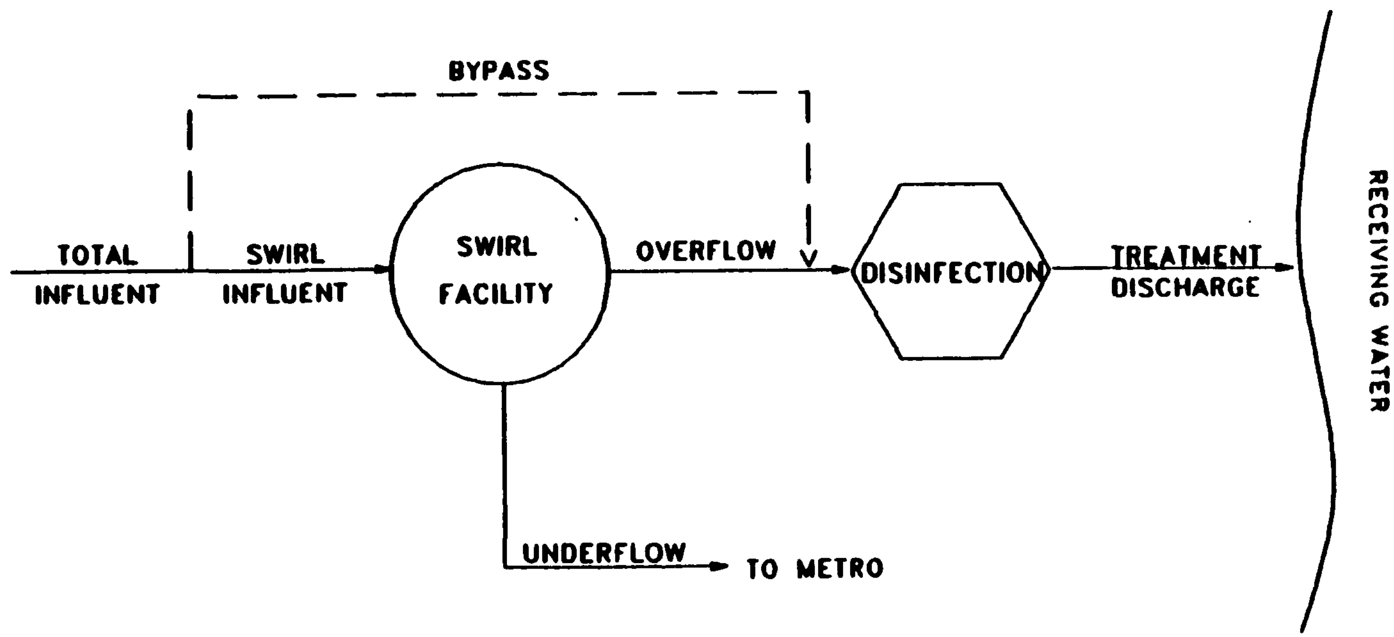
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

From: Moffa & Associates, 1990

Figure 35

Figure 35

FLOW SCHEMATIC FOR TYPICAL REGIONAL TREATMENT FACILITY



From: Moffa & Associates, 1991

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

**FLOW SCHEMATIC
REGIONAL FACILITIES**

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 36

Figure 36

Figure 36

collection system. The 90-percentile and 1-year storms were run through the collection system model to determine the adequacy of the proposed facilities. In many cases the collection system model identified areas of inadequacies, that have been subsequently corrected and incorporated into the regional facilities.

5.2.2.1 Onondaga Creek Regional Facilities

The high rate treatment facilities within the Onondaga Creek basin all follow the flow schematic as demonstrated on Figure 36. This figure shows that under overflow conditions, flow enters the swirl concentrator via a pumping station with the concentrated underflow being returned to the Main Interceptor Sewer. The swirl overflow receives disinfection prior to discharge to Onondaga Creek. For flow rates greater than the design rate, a portion of the influent flow from the CSO Interceptor Pipelines will be bypassed around the swirl facility and will join the flow which has gone through the swirl concentrator and receive disinfection.

5.2.2.1.1 Midland Service Area Regional Facilities

The Midland Area CSO Treatment Facility, which was recommended as part of the Preliminary Plans is located at Oxford Street and Onondaga Creek. The service area tributary to this facility encompasses the majority of the combined sewer area on the southern end of the city.

The proposed CSO Treatment Facility would include coarse screening, followed by pumping of the influent flow into a swirl concentrator for solids separation. Pumps would be used to lift the flow from the CSO transmission pipelines up to the swirl influent channel. Overflow from the swirl concentrator would be disinfected prior to discharge to Onondaga Creek. Concentrated solids from the Facility, known as "underflow," would be pumped back into the Main Interceptor Sewer (MIS) for treatment at the METRO STP. The 1979 Plan incorporated a "surge relief" or bypass weir to prevent flooding of the CSO Treatment Facility by storms larger than the 90-percentile event. Flows exiting the Facility through the bypass weir would not receive any treatment or disinfection.

There would be two major CSO Transmission Pipelines tributary to this facility. The first is the Midland Area CSO Transmission Pipeline which would intercept the major overflows to the South of the Treatment Facility. The second pipeline is the Tallman Street Transmission Pipeline which would intercept CSO's located to the north of the facility. Additionally, a transmission line was included to intercept the flow from a CSO which is located across Onondaga Creek from the proposed Midland Area CSO Treatment Facility. There are a number of CSO's that would not be connected to any proposed CSO Transmission Pipeline. The abatement of these CSO's was to be accomplished through sewer separation.

5.2.2.1.2 Clinton Station Area CSO Regional Facilities

The Clinton Station CSO Treatment Facility is located at the abandoned Clinton Station railroad yard, approximately 200 yards south of the Armory on Jefferson Street. This facility would provide treatment of CSO discharges for the central portion of the city.

The Treatment Facility would incorporate Archimedes screw pumps to lift the flow into a swirl concentrator. The overflow from the concentrator would then be disinfected and discharged to Onondaga Creek. This Facility, like the previously described Midland Area CSO Treatment Facility, would utilize inline pipe storage in combination with a limited pumping capacity to attenuate peak influent flow rates for the 90-percentile storm. Additionally, a surge relief and overflow (bypass) channel would be provided to carry storm flows in excess of the design storm. Any flows over the pumping capacity would be discharged without treatment or disinfection.

Four CSO transmission lines would be associated with this facility:

1. Clinton Street CSO Transmission Pipeline.

2. Onondaga Street CSO Transmission Pipeline.

3. West Street CSO Transmission Pipeline.

4. Jefferson Street CSO Transmission Pipeline.

5.2.2.1.3 Franklin Street CSO Treatment Facility

This proposed CSO Treatment Facility would be constructed near the intersection of Routes 690 and 81. At the recommended location, the two tributaries to this facility (Butternut and Burnet Avenue Trunk Sewers) are only 400 feet apart. An outfall pipe approximately 700 feet long would have to be constructed in conjunction with this facility.

The proposed facility would include screening by coarse bar racks before pumping which would lift flow to a common channel where it would be metered before discharge to a swirl regulator/concentrator. Underflow from the swirl would be pumped to the Burnet Avenue trunk sewer. The clarified swirl effluent would be disinfected using sodium hypochlorite.

Two short pipelines are necessary for implementation of this CSO Treatment Facility. They are referred to as the Butternut and Burnet Avenue CSO Transmission Pipelines.

5.2.2.1.4 Maltbie Street CSO Treatment Facility

As previously noted, Maltbie Street was the site of an EPA Demonstration Project during the 1970's. Facilities constructed as part of this project included a 15 MGD (23 cfs) pumping station and a number of microscreening units located in a sheet metal building. The 1979 Final Report recommended the removal of the microscreen units and the construction of a swirl concentrator. The discharge from the swirl concentrator would be disinfected in an existing chlorine contact tank. The existing pumps were estimated to be adequate in the Final Report for the 90-percentile storm. However, computer modeling done as part of the Facility Plan Update resulted in significantly higher flow rates.

Some of the originally proposed Maltbie Street CSO Transmission Pipeline has not been included within the current modeling effort. The only CSO transmission pipeline required for this facility will connect CSO's 065 and 066.

5.2.2.1.5 Newell Street CSO Demonstration Facility (existing)

A 12-foot diameter swirl concentrator exists at Newell Street on the southern end of the city. This unit, whose testing is responsible for much of the assumed high rate treatment facility removal efficiencies, was constructed as part of an EPA demonstration project. No CSO transmission pipelines will have to be constructed in conjunction with the upgrade of this facility.

5.2.2.1.6 Erie Boulevard CSO Treatment Facility

The Erie Boulevard CSO Treatment Facility would be located to the north side of Erie Boulevard and eastern bank of Onondaga Creek in what is a parking lot for Niagara Mohawk. It is probable that the unit would be located in such a manner as to minimize loss of space in that lot. Enough head should exist that quantity flow both into and out of a swirl regulator concentrator can be maintained, thereby, minimizing pumping expenses. Pumping would be necessary, however, to return the underflow from the unit to the Main Interceptor Sewer.

5.2.2.2 Harbor Brook Regional Facilities

The 1979 Final Report proposed three separate regional treatment facilities along Harbor Brook. Current regional interception schemes call for the consolidation of two of these facilities through an additional CSO transmission pipeline. The deteriorated condition of the Emerson Trunk sewer results in substantial maintenance efforts for OCDDS personnel. The replacement of this sewer would allow the above mentioned consolidation of the Emerson Avenue CSO Treatment Facility with the State Fair Boulevard CSO Treatment Facility. As such, only the Delaware Street and State Fair Boulevard Facilities would be included in a Harbor Brook Regional approach.

5.2.2.2.1 Delaware Street CSO Treatment Facility

The Delaware Street CSO Treatment Facility, included in the 1979 Final Report would be located on the northwestern corner of the intersection of Delaware Street and Grand Avenue. The Facility would provide treatment for CSOs within the upper portion of the Harbor Brook combined sewer system. This is the first regional treatment facility where the flow into the swirl is by gravity. After the flow has gone through the swirl and disinfection facilities, it is pumped out to Harbor Brook via Archimedes screw pumps. The proposed layout of the CSO Treatment Facility will not allow the associated CSO Transmission Pipelines to be used as in-line storage facilities for flow attenuation. Consequently, the swirl has to be designed for the "natural" peak flow and not a flattened out or attenuated flow.

This facility differs from the facilities discussed for the Onondaga Creek basin in that it does not incorporate any direct provision for flow bypassing. The primary impact induced by this arrangement is the variable removal

efficiencies that must be assumed for flows in excess of the design flow rate. This becomes important in the calculation of loads from the treatment facility. Flows that are in excess of the design flow would be restricted by the swirl influent channel and would be backed up and possibly overflow through either CSO 014 or 015.

There are two CSO Transmission Pipelines associated with the proposed CSO Treatment Facility. These are called the Rowland and Delaware Street CSO Transmission Pipelines.

5.2.2.2.2 State Fair Boulevard CSO Treatment Facility

The State Fair Boulevard CSO Treatment Facility recommended in the 1979 Final Report would be located between Erie and State Fair Boulevards at Rusin Street. This facility would provide treatment of the CSO discharges within the lower or northern portion of the Harbor Brook drainage basin. The general layout of the proposed CSO Treatment Facility is the same as the Delaware Street facility. In both instances, flow into and through the swirl concentrator is by gravity, followed by high rate disinfection and pumping into Harbor Brook. In addition to the replacement of the Emerson Trunk Sewer, there are two pipelines associated with the proposed State Fair Boulevard CSO Treatment Facility, the Hiawatha Boulevard CSO Transmission Pipeline and the State Fair Boulevard CSO Transmission Pipeline.

5.2.2.3 Ley Creek Regional CSO Treatment Facilities

There exist two separate CSOs within the natural Ley Creek drainage basin. No regional CSO Treatment Facilities were recommended for these sites in the 1979 Final Report. The need for CSO abatement facilities at these locations was addressed in the 1983 report by Calocerinos & Spina entitled "In-Water Combined Sewer Overflow Abatement Study."

5.2.2.3.1 Teall Avenue CSO Treatment Facility

This facility would be located on either the northwest or southwest corner of the intersection of Teall Avenue and Grant Boulevard. A major storm sewer connects to the CSO discharge line a short distance downstream from the overflow manhole. This storm sewer would have to be redirected so that the combined CSO and stormwater discharges would not have to be treated, just the CSO discharge. Overflow in the Ley Creek basin happens infrequently. This system barely overflows during the 90-percentile event. As such, if water quality modeling dictates the need to abate discharges only up to the 90-percentile storm level, then partial separation of the combined sewer area tributary to this overflow point would be appropriate. If water quality modeling determines that protection should be provided for the 1-year storm (or greater), then high rate treatment facilities are appropriate for this CSO.

CSO Transmission Pipelines associated with this regional facility would be very short and as such are not discussed here. The underflow sewer from the regional facility back to the Butternut Trunk Sewer could be laid in the same trench.

5.2.2.3.2 Hiawatha Boulevard CSO Treatment Facility

The Hiawatha Boulevard CSO Treatment Facility would be located to the northwest of the intersection of Hiawatha Boulevard and Spring Street, behind the Regional Market. This facility would provide treatment for overflows from the Hiawatha Trunk Sewer. The hydraulic analysis of this area is complicated by a number of different factors. Foremost is the identification of precise drainage boundaries to use in the modeling efforts. The general area is composed of both sanitary sewers and storm sewers. It is evident through the oversized sanitary trunk (42-inch) and the known catch basin connections that the sanitary system is in fact a combined sewer system. In addition to the unidentifiable area, there exists a fairly well defined combined sewer area. The overflow points for the area are underneath Route 81, and at Hiawatha Boulevard and Solar Street.

It is proposed that the Hiawatha CSO Treatment Facility be sized to include an assumed 50 percent of the area tributary to CSO 074 and all of the combined area from CSO 075. This will require the construction of a CSO Transmission Pipeline running northward along Hiawatha Boulevard, to provide for the flows from CSO 075's combined area, and an underflow force main connection (same trench) to the intersections of Hiawatha Boulevard and North Salina Street. In this manner, the crossing of Route 81 can be avoided and there will be no need to construct a CSO Treatment Facility in the vicinity of the intersections of Hiawatha Boulevard and Solar Street (Carousel Mall area).

It is doubtful that sewer system evaluation survey efforts and rehabilitation could reduce flows to the point where there would be no need for an overflow point. Moreover, the existing storm sewer system might not be able to handle the increased flow.

5.2.2.4 Summary of Regional Treatment Facilities

The following table summarizes the major parameters for the Regional CSO Facilities within the Onondaga Creek, Harbor Brook, and Ley Creek Drainage basins (Table 14).

Concentrated solids contained in the underflow from the swirl concentrators would be returned to the interceptor sewers for conveyance to the METRO STP. The net effect of this alternative would be to increase the magnitude of suspended solids and associated organic and nutrient loadings received at the METRO STP during wet weather conditions. The most significant impacts of regional CSO treatment on the operation and performance of the METRO STP will be associated with the additional suspended solids and fecal coliform loadings which would be received during wet weather conditions. Additional suspended solids loadings would impact the operation and performance of grit removal, primary settling, and sludge treatment facilities. Fecal coliform loadings would primarily impact operation and performance of stormwater bypass (primary effluent) chlorination facilities. This regional CSO treatment scheme would increase average thickener solids loading at METRO. Because effective sludge thickening is important to subsequent anaerobic sludge digestion and belt press sludge dewatering operations, expansion of the existing highly loaded sludge thickening

facilities (i.e., by construction of additional gravity thickeners, installation of mechanical sludge thickening equipment, etc.) will be required to reduce the impact of additional CSO solids. The extent of the expansion necessary will be dependent on other factors, including the method of phosphorus removal and the feasibility of pumping tertiary chemical sludge direct to dewatering, thereby bypassing gravity thickening and anaerobic digestion facilities. Fecal coliform loadings conveyed to METRO from regional CSO treatment facilities will increase the chlorine demand at the bypass chlorination facilities. At present, the bypass chlorination facilities are operated manually. The additional fecal coliform loadings from CSO treatment will increase chlorine dosage requirements and operator attention to prevent inadequate disinfection. (Stearns & Wheler, November 1990)

Table 14 Summary of Major Design Parameters for Regional Treatment Facilities

Facility Name	Drainage Basin	Design Flow (cfs) 90% Storm	Design Flow (cfs) 1-Year Storm	Swirl Diameter Feet 90% Storm	Swirl Diameter Feet 1-Year Storm
Midland	Onondaga Cr.	287	650	55	2 @ 61
Clinton	Onondaga Cr.	230	450	47	2 @ 48
Franklin	Onondaga Cr.	370	450	60	2 @ 48
Maltbie	Onondaga Cr.	70	145	28	35
Newell	Onondaga Cr.	11	23	12 (Exist.)	16 (New & Exist.)
Erie Blvd.	Onondaga Cr.	NA	150	NA	36
Delaware	Harbor Brook	170	275	40	53
State Fair	Harbor Brook	250	330	48	62
Teall	Ley Creek	NA	97	-	30
Hiawatha	Ley Creek	62	94	27	30

5.2.3 Centralized Collection/Treatment

The investigation of centralized transmission and treatment of CSO discharges was required as per the Workplan. The concept requires the collection of CSO discharges along Onondaga Creek and Harbor Brook and transmitting that flow to a central point in the vicinity of the METRO STP. The treatment of CSO discharges associated with the centralized concept would

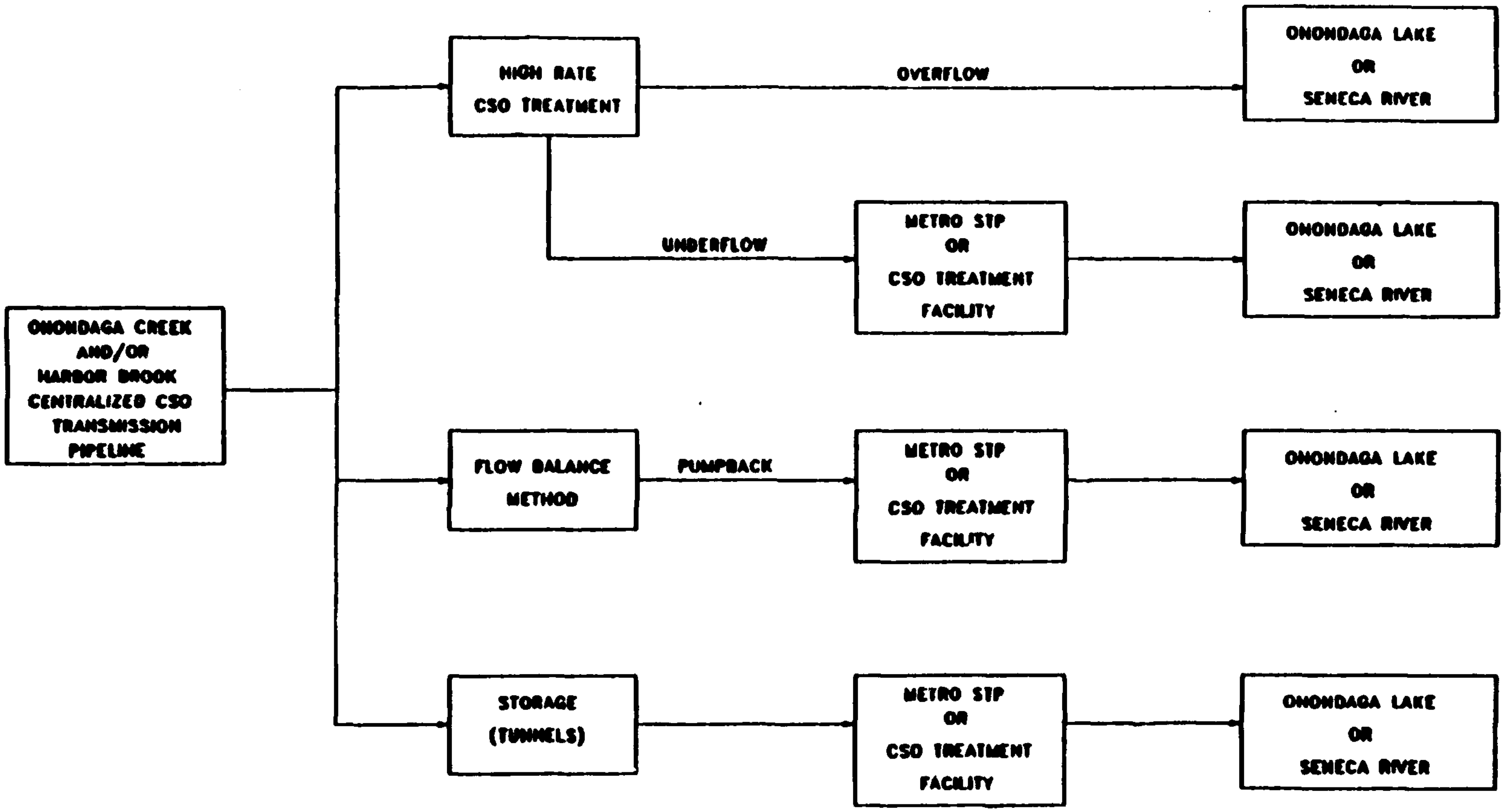
include as one alternative, the high rate treatment through swirl concentrators. Other alternatives include the discharge of flow to an In-Water Facility using the Flow Balancing Method (FBM) with pumpback provisions or tunnel storage with treatment at METRO or a (dedicated) CSO Treatment Facility. Discharge options with all centralized treatment alternatives include both Onondaga Lake and the Seneca River. The concept is shown in Figure 37, and the overall scheme is shown in Figure 38.

Advantages of the centralized approach to CSO abatement include the elimination of CSO discharges from the creeks for all storm events less than the design event and, under Seneca River discharges, the elimination of the CSO related pollutant discharges from Onondaga Lake. The elimination of stream discharges, particularly on Onondaga Creek, will represent an enhancement to fish passage as necessary for the goal of "Salmon 2000." The centralized concept can also be tied in with other "multiple use" goals such as the establishment of recreational facilities along the Onondaga Creek and Harbor Brook corridors (Creek-walk concept). Another important advantage with respect to water-contact or near-water facilities is the decreased rate of rise of Onondaga Creek and Harbor Brook that would be realized with centralized facilities. The analysis of hydrographs for Onondaga Creek (Spencer Street and Dorwin Avenue USGS Gaging Stations) has demonstrated that CSOs can constitute a high percentage of initial stream flows during summer periods when induced by thunderstorms. The containment of CSOs in centralized pipelines would reduce the hazard to the public.

Disadvantages include the cost of construction and the major construction obstacles that would be encountered with this approach. The construction of centralized facilities would be more disruptive and might require the reconstruction of bridges and a significant portion of the creek channel proper. For certain reaches of the stream, a centralized conduit for CSO transmission would have to be constructed within the floodway of the creek, thereby posing the possibility of increased flood potential problems.

The impacts of centralized high-rate CSO treatment facilities on the operation and performance of the METRO STP during wet weather conditions would be essentially the same as those discussed previously for the regional CSO treatment alternative. Due to the highly loaded conditions under which the METRO STP is presently operating, expansion of certain plant components (for example, sludge thickening facilities) is expected to be necessary in order to accommodate the additional loadings received as a result of either centralized high-rate CSO treatment or CSO storage with pump-back. The extent of expansion necessary will be dependent on other factors as well, including the need for additional treatment for improved phosphorus removal, ammonia removal, and nitrogen removal. For this reason, the impact on METRO facilities cannot be fully evaluated until such time that effluent requirements are more clearly defined. (Stearns & Wheler, November 1990)

This section is divided into discussions of the centralized pipelines that would be necessary under these alternatives, centralized high rate CSO treatment, in-lake storage (FBM) concepts, and tunnel storage.



From: Moffa & Associates, 1990

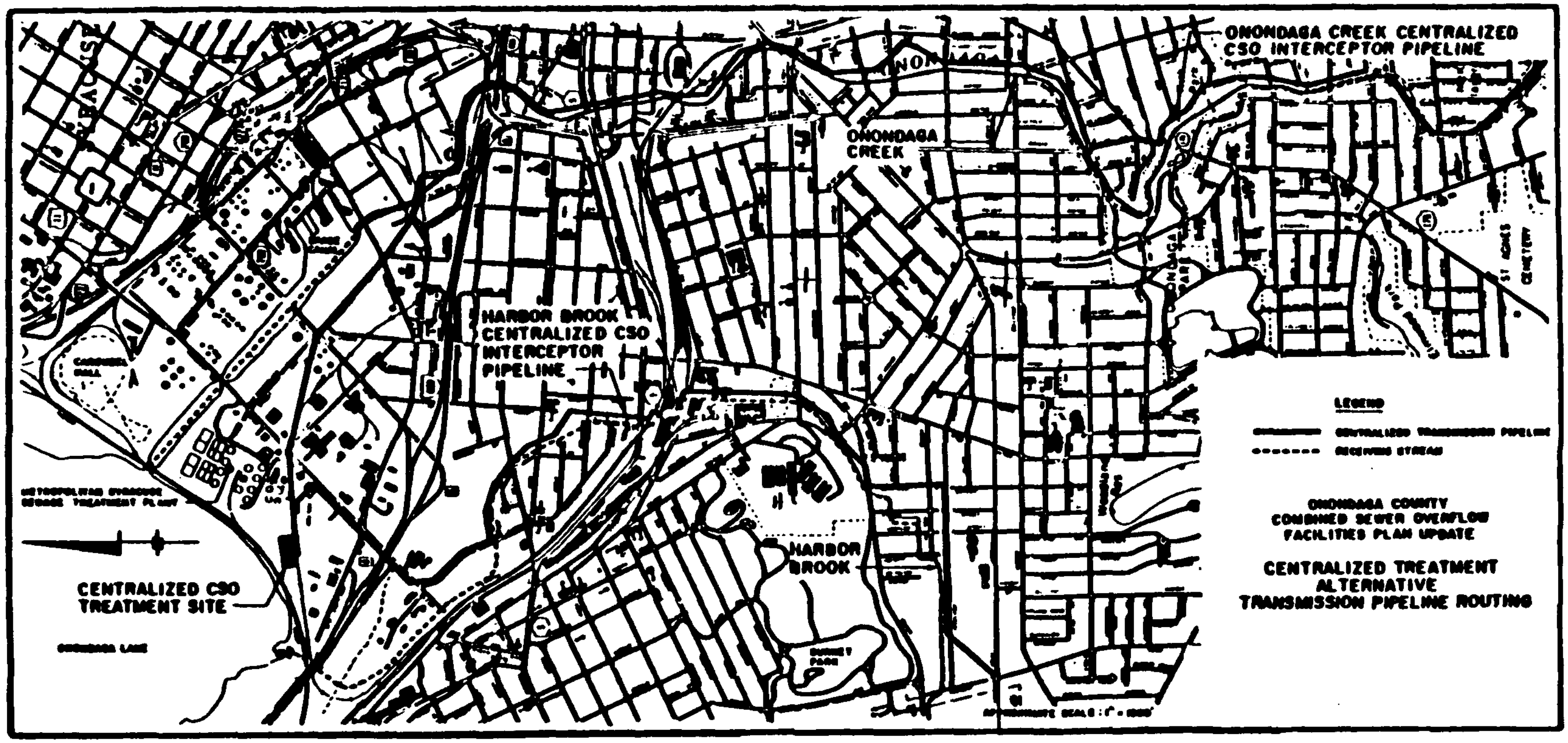
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CENTRALIZED CSO TREATMENT CONCEPT

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 37

Figure 37



From: Moffa & Associates, 1990

ONONDAGA LAKE

SYRACUSE, NEW YORK

RECONNAISSANCE REPORT

CENTRALIZED CSO TREATMENT SCHEME

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED:APRIL 1991

The in-water CSO abatement concept, a relatively new concept known as the Flow Balancing Method (FBM), is similar to an off-line storage system where CSO discharge is held until it can be pumped to a treatment facility. The major difference between the in-water system and a typical off-line system is that the actual storage occurs in a waterway, thus saving the expense of constructing comparable facilities on the shore.

The system, as shown on Figure 39, consists of pontoons and heavy-duty reinforced plastic curtains forming a series of compartments or bays. The flow enters the first bay and is forced through the series of bays via openings in the curtains. The flow displaces the receiving water which was in the system prior to the storm event. During and following the storm event, the captured volume is subject to settling and can then be pumped to a treatment facility where such treatment as disinfection can occur. As the captured volume is removed, the system again fills with receiving water.

An alternative mode of operation for in-water facilities is to have the treatment occurring within the facility rather than at a remote or adjacent treatment plant. Treatment processes which can be accomplished within the facility include settling and disinfection. This flow-through mode precludes the need for pumping the captured CSO and stream volume to a treatment plant. The flow-through mode is highly suitable for a location where there are limitations in available area or in treatment plant capacity and accessibility.

The in-water abatement system is advantageous since the process is relatively simple to both construct and operate, thus providing a major cost advantage over more complex, structurally-intensive CSO abatement facilities. Also, the facilities are essentially confined to the receiving water. This precludes the need to purchase and utilize highly valuable and expensive land in the city of Syracuse. A major problem with the FBM concept is the admitted use of the streams as conveyors of sewage.

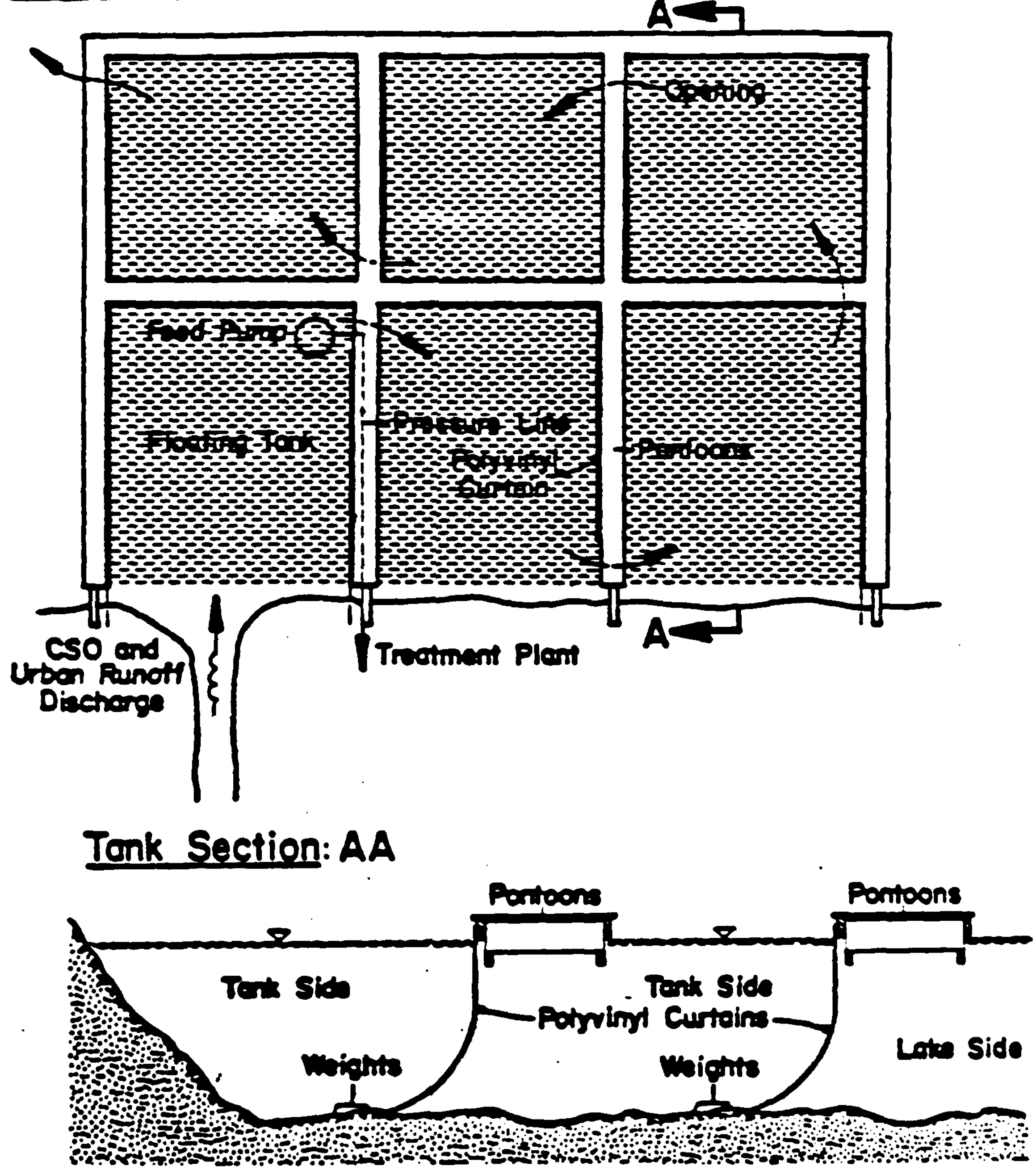
A related factor which makes the in-water system applicable and attractive is multi-use benefits. An in-water facility could be used as part of the Onondaga Lake trail system and it could also be used for small boat docking.

The prime objective of FBM facilities is disinfection; a secondary objective is settling of solids. Settling of solids has two (2) benefits: (1) reducing the disinfection requirements and (2) removing nutrients, attendant with the solids. Settling would occur continuously as long as the facilities are operating. Disinfection would only occur during a CSO event. These treatment processes would occur within the facilities when designed in the flow-through mode.

Flow-through treatment consists of primary treatment and disinfection. Facilities operating in the flow-through mode will be designed to remove floatable material and settleable solids to NYSDEC standards (0.8 ml/l), and disinfected to such a degree that fecal-coliform concentrations in the Class "B" section of the lake are less than 200 cells/100 ml.

The mechanism of solids removal in in-water facilities designed in the flow-through mode is analogous to a conventional sedimentation tank and is a function of the solids-settling velocity distribution. Two (2) types of

Typical In-Water CSO Abatement Facility



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TYPICAL IN-WATER CSO ABATEMENT FACILITY

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

From: Calocerinos & Spina, 1983

solids will be subject to capture in the in-water facilities: stream solids and CSO solids. Settling tests performed previously by O'Brien & Gere on six (6) CSOs and more recent treating of combined stream and CSO solids indicate that approximately 45 percent of the combined solids will be removed under average flow conditions (predicted from discrete particle settling analysis and solids scour velocity). That fraction of the nitrogen and phosphorus that is associated with both the stream and CSO solids will also be removed by the in-water facilities.

Despite the extreme flow rates that will be experienced, the disinfection system at in-water facilities is operated as a conventional-rate system since it would be impractical to provide sufficient mixing intensities to reduce the contact time.

Without external mixing at the point of disinfectant application, a diffuser system will be required to ensure uniform dispersion. This diffuser will consist of a header-lateral arrangement to distribute disinfectant over the entire open-channel cross section.

The lower strength and reduced variability of CSO-contaminated streamwater treated in in-water facilities decreases the required disinfectant-dosage rate and should result in more consistent performance.

Unlike a conventional sewage treatment plant, the in-water facilities will be subjected to extreme and rapidly fluctuating hydraulic loadings. Control of such facilities is dependent upon receiving and processing real-time data on CSO discharges and stream flow.

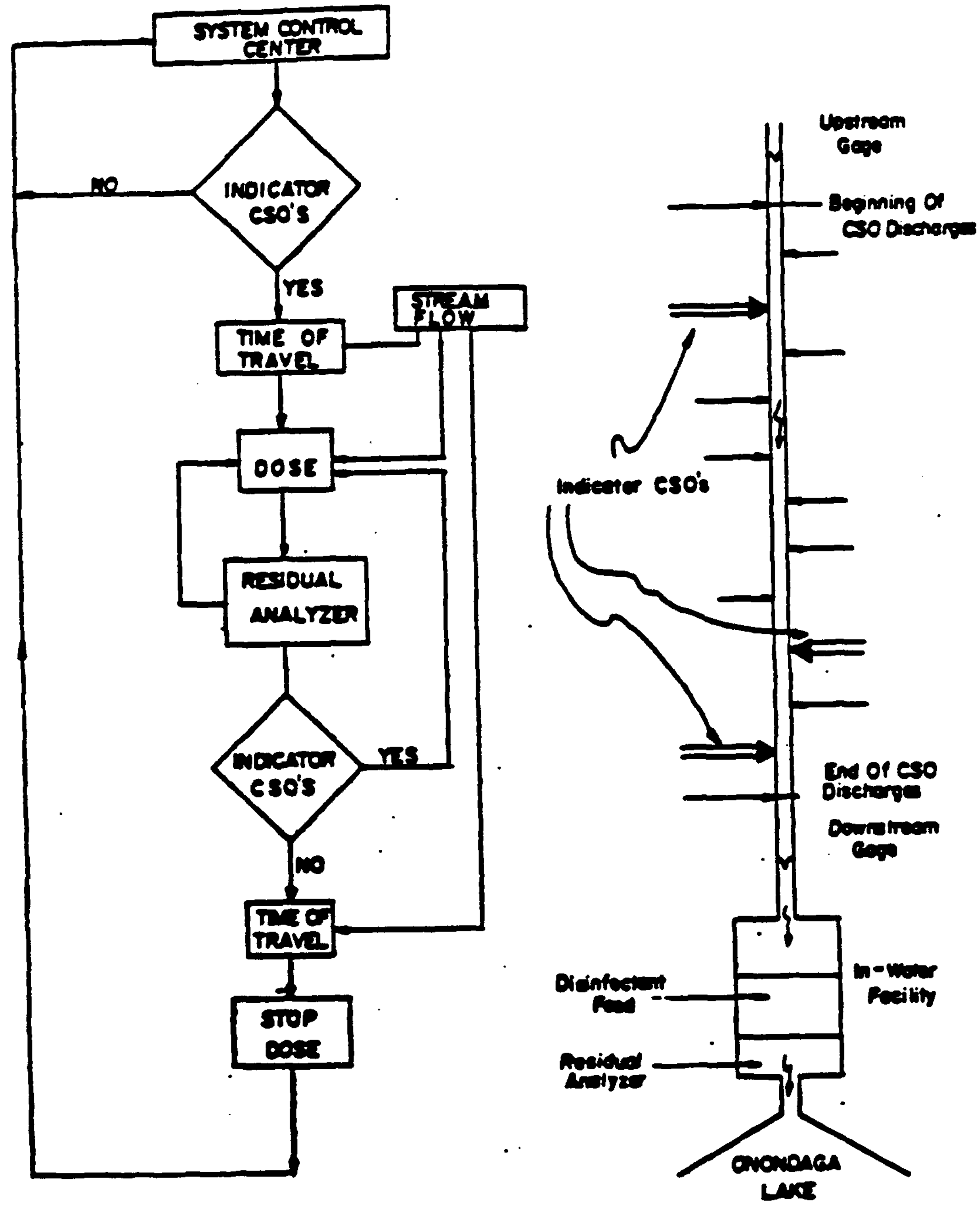
An important feature for a control system is time-of-travel (TOT) data. TOT data is determined through dye testing and/or velocity studies at a number of locations and at several flow regimes. TOT data is then related to upstream and downstream gages in order that the in-water facility control centers are provided with accurate information during and immediately following overflow events.

Another important feature for control systems is accurate information on whether or not CSOs are discharging. For this purpose, key indicating CSOs are selected for "overflow-status" monitoring. These CSOs would be those that discharge on a regular and consistent manner in relation to rainfall. Several such CSOs would be selected in order to have both accurate information on overflow occurrence and back-up capabilities.

One of the most important aspects of operating an in-water facility in a flow-through mode is the control of the proper dosage of disinfectant. The control logic for operating such a system is shown on Figure 40 and is described as follows:

(1) Key indicating CSOs on the stream begin to overflow, transmitting a signal to the control center.

(2) TOT along the stream between the downstream CSOs and the in-water facility is calculated based on real-time stream flow data from the downstream gage.



From: Calocerinos & Spina, 1983

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CONTROL SYSTEM FOR IN-WATER FACILITY DISINFECTION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 40

(3) Disinfectant is applied with the required dosage calculated from:

(a) Real-time stream flow, and

(b) Adjusted by a residual analyzer located in the facility.

(4) Key indicating CSOs signal the control center that they are no longer overflowing.

(5) TOT along the stream from the upstream CSOs is calculated based on real-time stream flow data from both the upstream and downstream gages.

(6) Disinfectant is no longer added following flow-through of the last volume of CSO-contaminated stream flow.

Another form of centralized collection treatment is in-line storage tunnels. These would be constructed along the same corridors as centralized pipelines but would be at greater depths and their diameters would be sized to store all of the flow generated during a design storm. Treatment would be provided at either METRO or a designated treatment facility, with ultimate discharge to either the lake or the Seneca River. The storage tunnel concept has been used in Chicago, Illinois and Milwaukee, Wisconsin.

5.2.3.1 Onondaga Creek Centralized CSO Interceptor Pipeline

The routing of the Onondaga Creek Centralized CSO Transmission Pipeline incorporates portions of the same routes of regional CSO Transmission Pipelines where applicable. The collection system model was used to develop a representation of a system with centralized transmission facilities. Separate models were developed for both the 90-percentile storm and the 1-year storm, for both the MIS and Harbor Brook systems. The lengths and diameters of required CSO Transmission Pipelines for the two different considered design storms are listed in Table 15..

5.2.3.2 High Rate Treatment Facilities - Onondaga Creek

The Onondaga Creek basin peak discharge for the 90-percentile storm is approximately half that of the 1-year storm (859 vs 1637 cfs). Centralized treatment facilities would have to provide treatment for these rates. Pumping would be necessary to lift the flow from the centralized pipeline into a high-rate treatment facility.

5.2.3.3 FBM Facilities - Onondaga Creek

The construction of "Flow-Balance Method" or "In-Water Facilities" for the capture of Onondaga Creek has a number of serious drawbacks. Foremost, it would require the acknowledged use of Onondaga Creek as a sewer, with all of the previously stated objections by NYSDEC. Additionally, it would represent an obstruction to fish migration that does not appear compatible with the long range goals for this body of water. Moreover, a relatively large basin would be necessary for the capture of the 1-year storm. For these reasons, an FBM facility was not considered for Onondaga Creek by itself.

However, the FBM would be a viable solution for the temporary storage of CSO discharges from a centralized pipeline. The volumes of storage required for the 90-percentile and 1-year design storms would be 7.2 and 15.4 million cubic feet, respectively.

Table 15 Centralized Facility - Pipeline Summary

Service Area	Section Location	Length	Pipe Diameter (Ft) 90% Storm	1 Yr. Storm
MIS	W. Brighton to Kirk Park	300'	3	4
MIS	Kirk Park to Elmhurst	300'	3	4
MIS	Elmhurst to W. Colvin	800'	5	6
MIS	W. Colvin to Park Dr.	300'	6	7
MIS	Park Dr. to South Ave.	3200'	6	7
MIS	South Ave. to Blain St.	1400'	8	9
MIS	Blain St. to Tallman St.	1300'	13	14
MIS	Tallman St. to W. Adams St.	2460'	13	14
MIS	W. Adams St. to E. Onondaga St.	640'	13	14
MIS	E. Onondaga St. to Walton St.	1640'	13	15
MIS	Walton St. to E. Fayette St.	360'	13	16
MIS	E. Fayette St. to Erie Blvd.	800'	13	18
MIS	Erie Blvd. to Rte. 690	1500'	15	18
MIS	Rte. 690 to Plum St.	1500'	15	18
MIS	Plum St. to CSO Centralized Facility	5800'	15	18
		22,300		
HBIS	Velasko Rd. to Rowland St.	940'	4	4
HBIS	Rowland St. to Hoefler St.	1570'	5	5
HBIS	Hoeffer St. to Lydell St.	680'	5.5	6
HBIS	Lydell St. to Herrriman St.	570'	5.5	6
HBIS	Herriman St. to Deleware St.	980'	5.5	6
HBIS	Deleware St. to Seymour St.	680'	6.5	7
HBIS	Seymour St. to Gifford St.	370'	6.5	7
HBIS	Gifford St. to W. Fayette St.	1480'	6.5	8
HBIS	W. Fayette St. to W. Fayette St.	250'	6.5	8
HBIS	W. Fayette St. to Richmond Ave.	1390'	7	8
HBIS	Richmond Ave. to Park St.	400'	7	8
HBIS	Park St. to W. Genesee St.	350'	7	8
HBIS	W. Genesee St. to State Fair Blvd.	2330'	8	9
HBIS	State Fair Blvd. to W. Hiawatha	550'	8	9
HBIS	W. Hiawatha to CSO Treatment Facility	1500'	8.5	9.5
		14,570		

5.2.3.4 In-Line Storage Tunnels - Onondaga Creek

In-line storage tunnels could be constructed to temporarily store the total overflow from either design storm. The associated volumes of storage required are the same as the values noted for the FBM facility. These tunnels would be constructed below the ground surface, thereby minimizing conflicts with surface utilities. The diameter of the tunnel is determined knowing the length (approximately 22,300 feet) and storage volume required. The necessary diameter for the MIS centralized tunnel has been calculated at 20.5 feet for the 90-percentile storm and 30 feet for the 1-year storm.

5.2.3.5 Harbor Brook CSO Interceptor Pipeline

As was the case with the Onondaga Creek centralized conduit, separate centralized collection system models were developed for Harbor Brook. The lengths and diameters of CSO Interceptor Pipelines for the two different design storms are shown on the previously referenced Table 18.

5.2.3.6 High Rate Treatment Facilities - Harbor Brook

The Harbor Brook basin peak discharge for the 90-percentile storm is a little more than half that of the 1-year storm (188 vs 367 cfs). Centralized treatment facilities would have to provide treatment for these rates. As in the case for the Onondaga Creek CSO Centralized Treatment Facilities pumping would be necessary to lift the flow from the centralized pipeline into a high-rate treatment facility.

5.2.3.7 FBM Facilities - Harbor Brook

In-water facilities for the Harbor Brook Basin could be sized in two separate manners. First, the facility could be sized to take the discharge from a 90-percentile and 1-year storm from the Harbor Brook centralized CSO Transmission Pipeline. In this case, the FBM Facility would have to provide containment for 0.62 and 1.05 million cubic feet for the 90-percentile and 1-year storms, respectively.

The alternate approach would be to take the entire discharge for Harbor Brook itself and capture it. This has the advantage of not requiring the centralized pipeline, which would be a considerable savings. The approach would, however, require the construction of a larger FBM Facility due to the fact that brook water would be captured as well. Analysis shows a 90-percentile storm volume of 3.0 million cubic feet and the corresponding value for the 1-year storm is 7.0 million cubic feet.

One manner to reduce the volumes associated with the capture of the brook proper, requires modifications to the upstream Velasko Road storm detention basin. If this basin's size is increased and the outlet structure modified for maximum runoff period storage, then the FBM capacity could be reduced. Also required under this scenario will be the construction of a portion of the CSO Transmission Pipeline to intercept the discharge for CSOs 078 and 018 and discharge them into the brook below the detention pond outlet structure.

5.2.3.8 In-Line Storage Tunnels - Harbor Brook

The diameters of in-line storage tunnels for the Harbor Brook basin are calculated in a similar manner as those along Onondaga Creek. Assuming an effective length of 14,570 feet, the required diameters for the 90-percentile and 1-year storm pipelines are 11.5 and 17.5 feet, respectively.

5.2.3.9 Ley Creek Facilities

No centralized CSO Transmission Facilities or high rate CSO Treatment Facilities were considered for this basin or incorporated into the workplan.

FBM Facilities were not considered due to the low ratio of CSO volume to total creek volume that would exist. The loading calculations for this basin demonstrate the relative non-importance of pollutants discharged on an annual basis.

Both of the CSOs in the Ley Creek basin are remote from each other and the METRO STP. Any centralized treatment scheme would require the construction of long pipelines and would have very low cost-benefit ratios, based upon water quality impacts.

5.2.3.10 Combination of Onondaga Creek and Harbor Brook

The proposed routes for both the Onondaga Creek and Harbor Brook Centralized CSO Interceptor Pipeline lead to a site on the western side of the METRO STP grounds. At this location, the flows could be either treated individually or collectively.

5.2.3.11 High Rate Treatment Facilities - Onondaga Creek and Harbor Brook

The Onondaga Creek and Harbor Brook total peak flows for the 90-percentile and 1-year storms are 915 and 1,714 cfs, respectively. The peak underflow flow rates to the METRO STP or a dedicated facility to treat high rate centralized flows have been determined to be 46 and 86 cfs. The consolidation of high rate treatment facilities on the METRO grounds would result in a decreased capital cost and increased operational flexibility. This would be important from the spatial variability of rainfall standpoint.

5.2.3.12 FBM Facilities - Onondaga Creek and Harbor Brook

The combined discharge of the Onondaga Creek and Harbor Brook Centralized CSO Interceptor Pipelines into a common FBM Facility would also be a more efficient operation than separate FBM Facilities. The volume required for a 90-percentile storm combined facility would be 8.7 million cubic feet. The corresponding value for the 1-year storm is 18.9 million cubic feet.

A sub-alternative exists, as previously noted, that includes the capture of Harbor Brook itself. Such a facility could be sized to include the discharge of the Onondaga Creek Centralized CSO Interceptor Pipelines as well. The estimated combined 90-percentile and 1-year storm volumes are 10.2 and 22.4 million cubic feet, respectively. A possibility exists to reduce the

design storm volumes associated with Harbor Brook itself. As noted in the discussion of the Harbor Brook basin, modifications to the Velasko Road storm detention basin would be required as well as redirection of the discharge of two CSO discharges. Sizes have not been developed for the FBM Facilities associated with this latter sub-alternative.

5.2.3.13 In-Line Storage Tunnels - Onondaga Creek and Harbor Brook

The construction of intersecting in-line storage tunnels for the Onondaga Creek and Harbor Brook Centralized CSO Interceptor Pipeline is another possibility. The concept would not result in any appreciable cost savings for pipeline construction, but it would provide for increased operational flexibility when there is a rainfall event with significant variability. Either pipeline could be used to store CSO discharges in the other if capacity was available. The storage tunnels would be pumped down over a period of 2 or 3 days to allow storage for the next overflow event. Treatment would be provided at either METRO STP or a dedicated CSO Treatment Facility.

5.2.4 Detention Reservoirs

Detention reservoirs were investigated during the earlier CSO studies for the METRO service area and were eliminated due to space restrictions and prohibitive costs. The available storage in trunk sewers, interceptor pipelines and swirl concentrators was considered under the present alternatives. In addition, limited detention basin analysis was included with an FBM facility for Harbor Brook.

5.3 Sediments

5.3.1 Dredging

Onondaga Lake is approximately 4.5 miles long and 1 mile wide and has a mean depth of 40 feet (New York State Department of Environmental Conservation, 1989). Roughly one-third of the lake is greater than or equal to 50 feet in depth with a maximum depth of 65 feet. It is accessible from Lake Ontario via the Oswego Canal and Erie Canal systems. The minimum water depth available on the canal system is 12 feet at ordinary water stage. The minimum horizontal clearance available from Lake Ontario to Onondaga Lake is 75 feet while the minimum vertical clearance is 19 feet at Maximum Navigable Pool.

As a result of industrial activities surrounding Onondaga Lake there has been significant discharges of mercury and alkali-wastes (including calcium chloride, sodium chloride, calcium sulfate, and calcium carbonate) into the lake. High concentrations and a wide distribution of mercury have been found in the lake sediment with contaminated sediments ranging from shallow near shore areas to the deepest parts of the lake. The volume of excavation required to remove sediment containing mercury concentrations greater than or equal to 1.0 parts per million (ppm) has been estimated at 6,500,000 cubic yards covering an area of 2,610 acres while the volume of excavation required to remove sediment containing mercury concentrations of 5.0 ppm or greater has been estimated at 3,000,000 cubic yards over an area of approximately 2,140 acres. Approximately 2,000,000 cubic yards of sediment covering an area of

approximately 1,880 acres would require excavation to remove material containing mercury concentrations greater than or equal to 10.0 ppm (see Figures 41 through 43). Sediment volumes were computed based on mercury concentration contours shown for various depths of sediments (New York State Department of Environmental Conservation, 1989). The contour areas for 1, 5, and 10 parts per million were determined and multiplied by the appropriate depth of sediment. It is anticipated that most of the sediments will be in the silt and clay size range (Rowell, 1990).

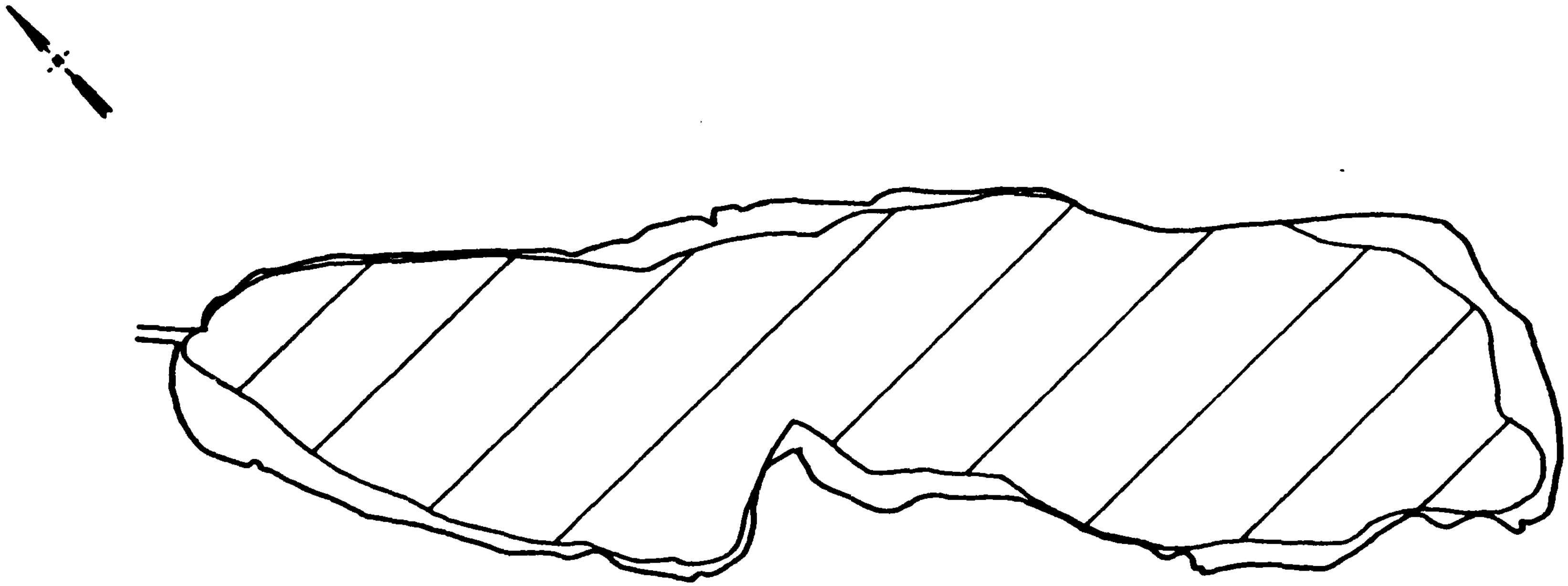
5.3.1.1 Dredging Equipment

Selection of the proper dredging equipment for this project included analysis of the characteristics and quantity of sediments, dredging depth, level of contamination and resuspension of contaminated sediments, limitations of the Oswego and Erie Canal systems, and distance to and type of disposal alternatives. There are several types of dredges that may be suitable for removing the contaminated Onondaga Lake sediments. These dredges fall into three broad categories; hydraulic, mechanical, and special purpose dredges. The material that would be dredged has high concentrations of contaminants. When the sediments are disturbed, such as by dredging, contaminants may be transferred to the water column through resuspension of the sediments, dispersal of interstitial water, or desorption from the resuspended solids. Generally, almost all the contaminants transferred to the water column are due to the resuspension of solids. Therefore, the release of contaminants can be reduced by limiting the resuspension of solids during the dredging and disposal operations (Palermo, 1988).

5.3.1.1.1 Mechanical Dredges

It has been shown that mechanical dredges produce higher suspended sediment levels than hydraulic dredges (Hayes, Raymond, McLellan, 1984). The clamshell (bucket) and enclosed clamshell (watertight bucket) were the only mechanical dredges that were considered for removal of contaminated Onondaga Lake sediments. The clamshell dredge is readily available throughout the United States in different sizes, boom lengths, and bucket sizes. Clamshell dredges are usually barge mounted and transported by tugs and in most cases anchors and spuds are used to position and move the barge during dredging (Figure 44). Dredged material is typically loaded into scows or barges and towed to the disposal site. A minimum draft of 6 feet is required for the dredge and barges. The clamshell dredging process creates a large amount of resuspended solids when the bucket impacts the sediments, is drawn from the sediments, pulled through the water column and drains above the water as it loads sediments into the barge (Averett, Perry, Torrey, 1989). The clamshell also leaves an irregular, cratered bottom, resulting in some contaminated sediments not being dredged. Table 16 summarizes operational characteristics of this and other dredges considered.

An enclosed clamshell is a special bucket designed to enclose excavated material so sediment resuspension caused by pulling the bucket through the water column and draining above the water is minimized. A tongue and groove edge seals the bucket when it is closed. A comparison of the two types of buckets indicates that enclosed buckets generate 30 to 70 percent less



From: NYS DEC, 1989

SCALE : $1^{IN} = 3075^{FT}$

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SEDIMENTS CONTAINING MERCURY CONCENTRATIONS GREATER THAN OR EQUAL TO 1 PPM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 41

Figure 41

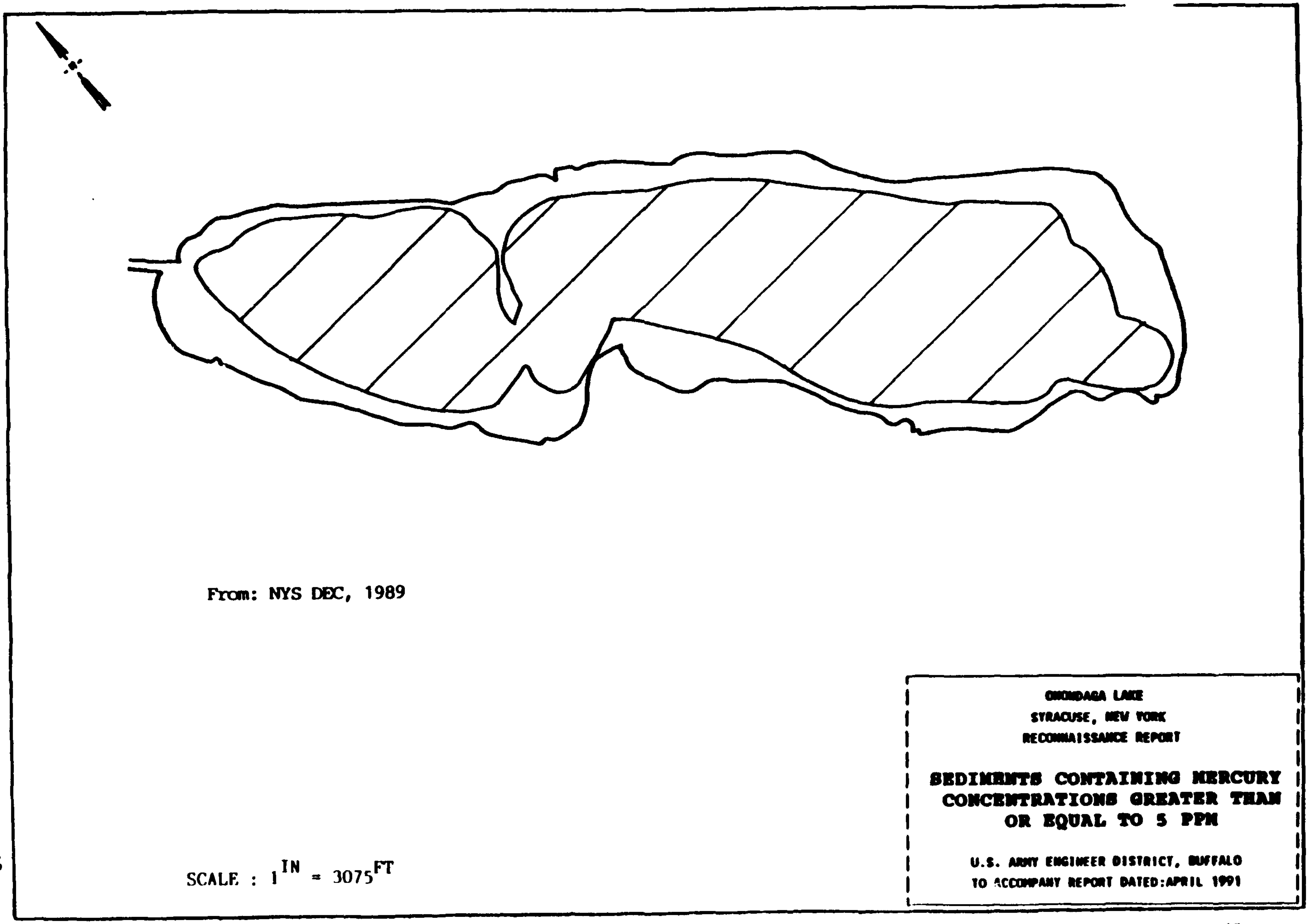


Figure 42

Figure 42

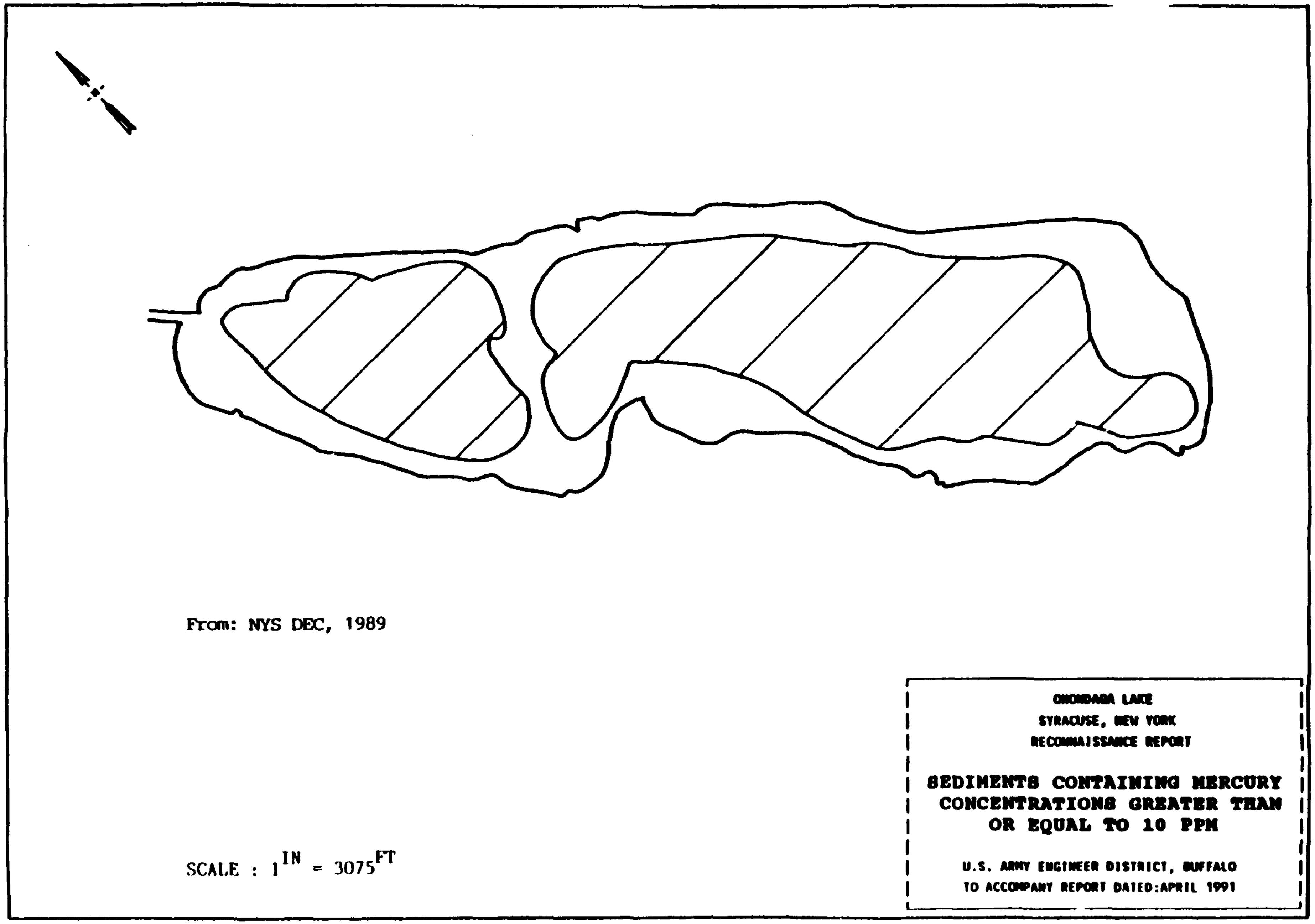
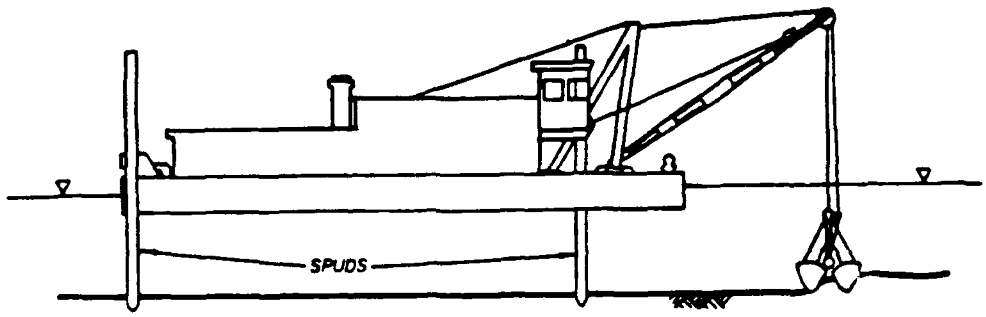
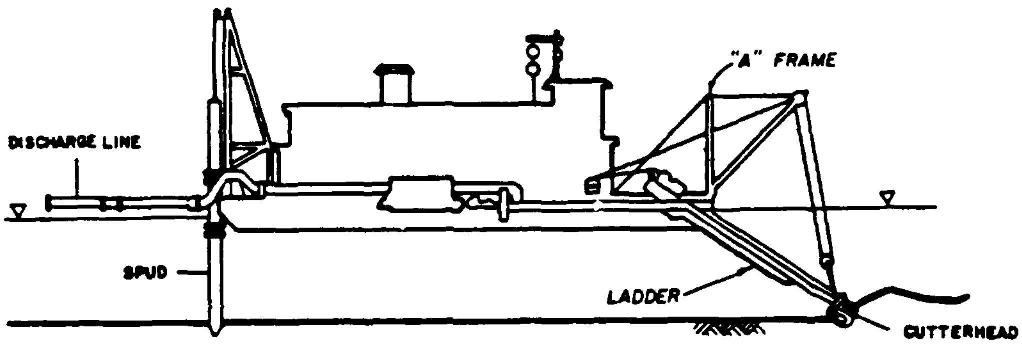


Figure 43

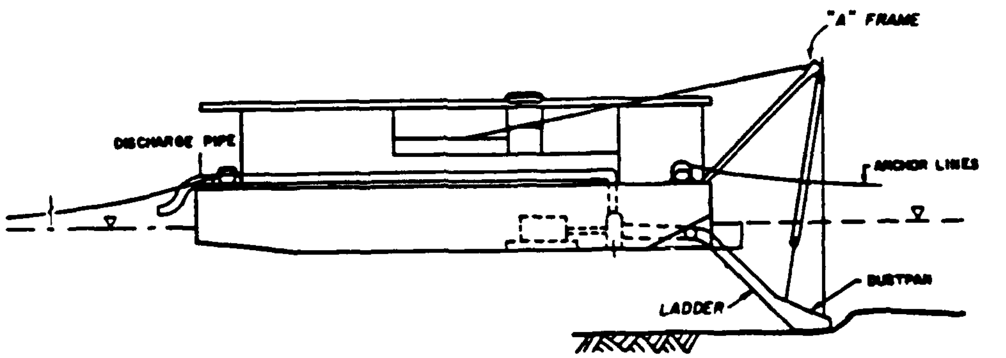
Figure 43



Bucket dredge



Hydraulic pipeline cutterhead dredge



Dustpan dredge

From: Palermo, 1988

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

BUCKET, CUTTERHEAD AND DUSTPAN DREDGES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Table 16 - Summary of Dredge Operating Characteristics

Dredge Type	Percent Solids in Slurry by Weight [b]	Turbidity Caused	Open-Water Operation	Vessel Draft ft	Approx. Range of Production Rates cu yd/hr	Dredging Depths ft Minimum	Maximum	Availability	Lateral Dredging Accuracy Ft	Vertical Dredging Accuracy Ft
Clamshell	in situ	high [c]	yes [d]	[e]	30-500	0 [f]	100 [g]	Available	1	2
Dustpan	10-20%	average	no	5-14	25-5,000	5-14	50-60 [h]	Limited	2-3	1/2
Cutterhead	10-20%	average	yes [d]	3-14	25-10,000	3-14	12-65 [h]	Available	2-3	1
Hopper	10-20%	average	yes	12-31	500-2,000	10-28	80	Available	10	2
Suction	10-15%	average	yes [d]	3-14	25-5,000	3-14	12-65	Available	2-3	1
PNEUMA	up to 80%	very low	yes	5-8	60-2,600	12	150	Proprietary	1	1
Clean-Up	30-40%	very low			500-2,000			Foreign	2-3	1
Matchbox	near in situ	very low						Proprietary		
Waterless	30-50%	very low			small dredge	shallow		Proprietary		
Refresher	30-40%	very low			200-1,300			Foreign	2-3	1

a. Prepared with information obtained from referenced COE reports
b. Percent solids could theoretically be 0, but these are normal working ranges. Percent solids = $\frac{\text{wt. of dry sediment}}{\text{wt. of wet slurry}}$.

c. Low, if watertight clamshell is used.
d. Limited operation in open water possible, depending on hull size and type and wave height.
e. Depends on floating structure; if barge-mounted, approximately 5- to 6-ft draft.
f. Zero if used alongside of waterway; otherwise, draft of vessel will determine.
g. Demonstrated depth; theoretically could be used much deeper.
h. With submerged dredge pumps, dredging depths have been increased to 100 ft or more.

·rbidity in the water column than typical buckets, primarily due to a :ction in leakage of dredged material from the enclosed bucket (Department .e Army, 1983). The enclosed clamshell also leaves an irregular, cratered :om, meaning some contaminated sediments may not be removed.

5.3.1.1.2 Hydraulic Dredges

The hydraulic dredges tend to generate less turbidity than mechanical dredges. This is particularly true of the conventional cutterhead dredge and for hopper dredges where overflow is not allowed (Hayes, Raymond, McLellan, 1984). The hopper dredge may be the most economical type of dredge to use where disposal areas are not available within economic pumping distances. They have excellent maneuverability, good production rates, and are best suited for dredging deep harbors and channels. Material is excavated and pumped through the dragarm of a hopper dredge and into hoppers located in the vessel hull. However, due to the limitations of the Oswego and Erie Canal systems, a minimum vertical clearance of 19 feet, it is not feasible to use a hopper dredge on Onondaga Lake. Hoppers typically have vertical clearance requirements in excess of 60 feet (Department of the Army, 1983).

The hydraulic pipeline cutterhead dredge is generally the most efficient and versatile and the most commonly used dredge in the country (Figure 44 and Table 17). It can efficiently dig and pump all types of material from soft to compact deposits, hardpan, and rock. It can excavate materials ranging from clays to gravels and can pump dredgings long distances. The cutterhead dredge is generally classified by size in accordance with the diameter of the discharge pipeline and has a production rate ranging from 25 to 10,000 cubic yards per hour. While the sediment resuspension rate of the cutterhead is not as low as some dredges, it has been described as the logical selection for controlling sediment resuspension while maintaining efficient production. The suspended solids plume is usually contained in the lower portion of the water column. Tests have concluded that the cutterhead showed very little resuspension when operated properly (Hayes, McLellan, Truitt, 1988).

The suction dredge is a hydraulic pipeline cutterhead dredge with the cutterhead removed. The operations, production rates, and dredging depths for the suction dredge are similar to those of the cutterhead pipeline dredge. The suction dredge generates low levels of turbidity but is capable of dredging only soft free-flowing material, free of large debris which tends to clog the suction dredge.

The dustpan dredge is a hydraulic suction dredge that uses a widely flared dredge head containing pressure water jets (Figure 44). The dredge is designed to operate in shallow water with free flowing sandy sediments. Dustpan dredges generate suspended solids plumes similar to or greater in concentration than plumes generated by cutterhead dredges with sediment resuspension concentrated in the area of the dustpan head. Dustpan dredges have a production rate ranging from 25 to 5,000 cubic yards per hour (Palermo, 1988), however, dredged material can be raised only a few feet above the water surface and pumped a short distance (Averett, Perry, Torrey, 1989).

Generally, hydraulic dredges remove around 4 volumes of water for every volume of sediment, whereas, mechanical dredges remove sediments with minimal additional water.

Table 17 - Specifications for Typical Cutterhead Dredges

Dredge Type	Pipeline Diameter in.	Weight tons	Length ft	Width ft	Height ft	Draft in.	Freeboard in.	Dredge Pumps No.	hp	Size	Drive	Production Rate cu yd/hr	Dredging Depth ft	Maximum Depth of Single Pass Excavation in.
Cutterhead	6	18.5	44	11	20	34	14	1	175	8	Diesel	25-95	12	18
Cutterhead	8	18.5	44	11	20	35	13	1	175	8	Diesel	45-015	12	18
Cutterhead	10	72.5	90	17	33	43	17	1	335	12	Diesel	60-300	25	18
Cutterhead	12	73.5	90	20	33	42	18	1	520	14	Diesel	120-540	25	18
Cutterhead	14	87	95	20	33	43	17	1	520	16	Diesel	160-700	25	21
Cutterhead	16	166	130	28	55	55	17	1	1125	18	Diesel	240-875	40	21
Cutterhead	20	316	180	32	70	54	42	1	1700	24	Diesel	310-1365	50	24
Cutterhead	24	326	185	32	70	56	40	1	2250	24	Diesel	515-1615	50	30
Cutterhead	30	350	225	36	67	60	36	1	3600	30	Diesel	575-2500	50	36

5.3.1.1.3 Pneumatic Dredges

Pneumatic dredge systems use compressed air to pump a sediment slurry -ough a pipeline. Pressure differential between the pressure in the pump ·ber and the hydrostatic pressure of water outside the pump forces water sediment into the chamber. The entrance valve is then closed and air is pumped into the chamber, increasing pressure and forcing the slurry out of the discharge valve. The PNEUMA pump pneumatic dredge is mounted on a barge with a crane to raise and lower the pump body and pull it through the sediments (Figure 45). Different opening configurations are used to remove different sediments. Turbidity levels around the PNEUMA dredge are extremely low, and high concentrations of low-viscosity material can be dredged (Table 16). The capacity of a large plant is 2,600 cubic yards per hour and has been used in water depths of 150 feet. The PNEUMA system dismantles easily for transport by trucks or air and has been used extensively in Europe and Japan and is available in the United States. PNEUMA will not operate satisfactorily in water depths less than approximately 12 feet (Averett, Perry, Torrey, 1989).

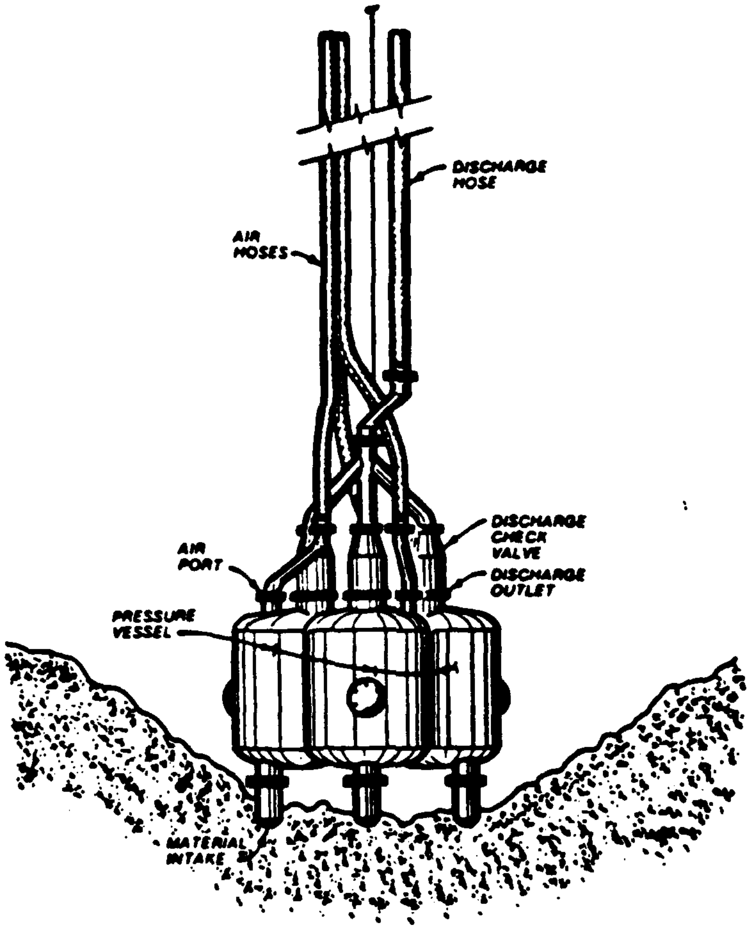
5.3.1.1.4 Specialty Dredges

Numerous specialty dredges have been developed throughout the world including the clean-up dredge, matchbox dredge, waterless dredge, and refresher system. Many of the specialty dredges were developed to pump dredged material slurry with a high solids content and/or to reduce sediment resuspension at the dredgehead. The clean-up dredge was developed by the Japanese for dredging highly contaminated sediments. Its head consists of a shielded auger that collects sediment as the dredge swings. A movable wing covers the sediment as it is collected by the auger (Figure 46).

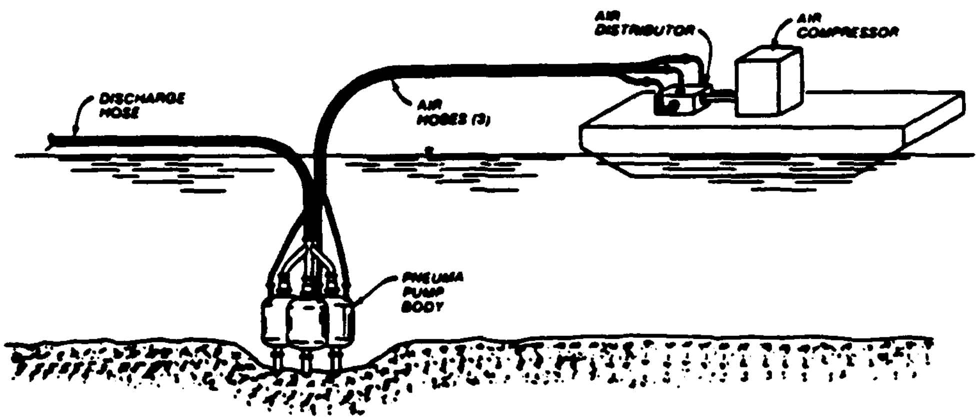
The matchbox dredge is a suction dredge head enclosed in a housing that resembles a matchbox (Figure 46). It is designed to dredge fine-grained sediments at near in-situ density and keep resuspension to a minimum. This dredge effectively removed contaminated sediment with a minimum loss of suspended solids during the new Bedford Superfund Pilot Study (New England Division, U.S. Army Corps of Engineers, 1989).

The waterless dredge encloses the cutter and centrifugal pump in a half-cylindercal shroud. As the cutterhead is forced into the sediments, the cutting blades remove the material near the front of the cutterhead with little entrainment of water. The manufacturer estimates a solids content of 30 to 50 percent by weight with very little turbidity. Dredge pipeline sizes range from 6 to 12 inches, a small-class pipeline dredge. This system has been used successfully in Connecticut to remove contaminated sediment (USEPA, 1985).

The refresher system developed by the Japanese is a modification of the cutterhead dredge. It uses a helical shaped gather head to feed sediments into the suction, with a cover over the head to reduce resuspension. Under testing in similar material the refresher system produced suspended sediment levels of from 4 to 23 mg/l within 10 feet of the dredge head as compared to 200 mg/l with a conventional cutterhead dredge. Production for the cutterhead (26 inch discharge) was 800 cubic yards per hour while production with the refresher system (17 inch discharge) was 350 cubic yards per hour. It was felt that the refresher system produced 1/50 of the total resuspension produced by the cutterhead dredge (Kaneko, Watari, Aritomi, in press).



PNEUMA Pump Body



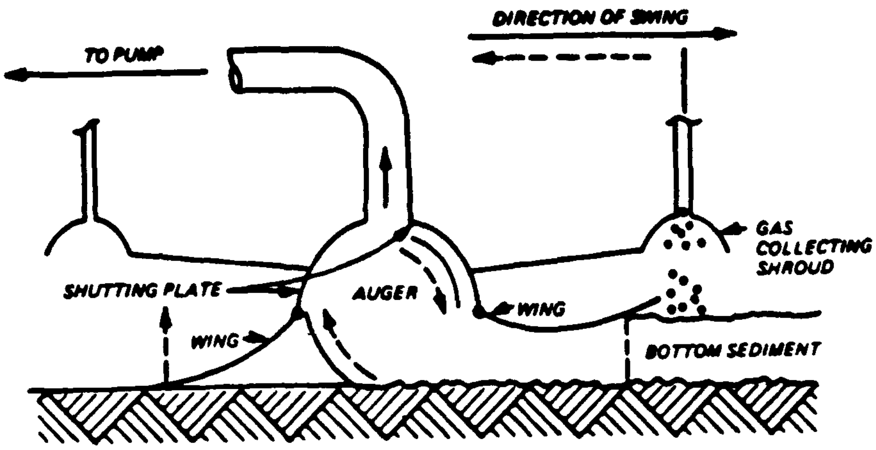
PNEUMA pump

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

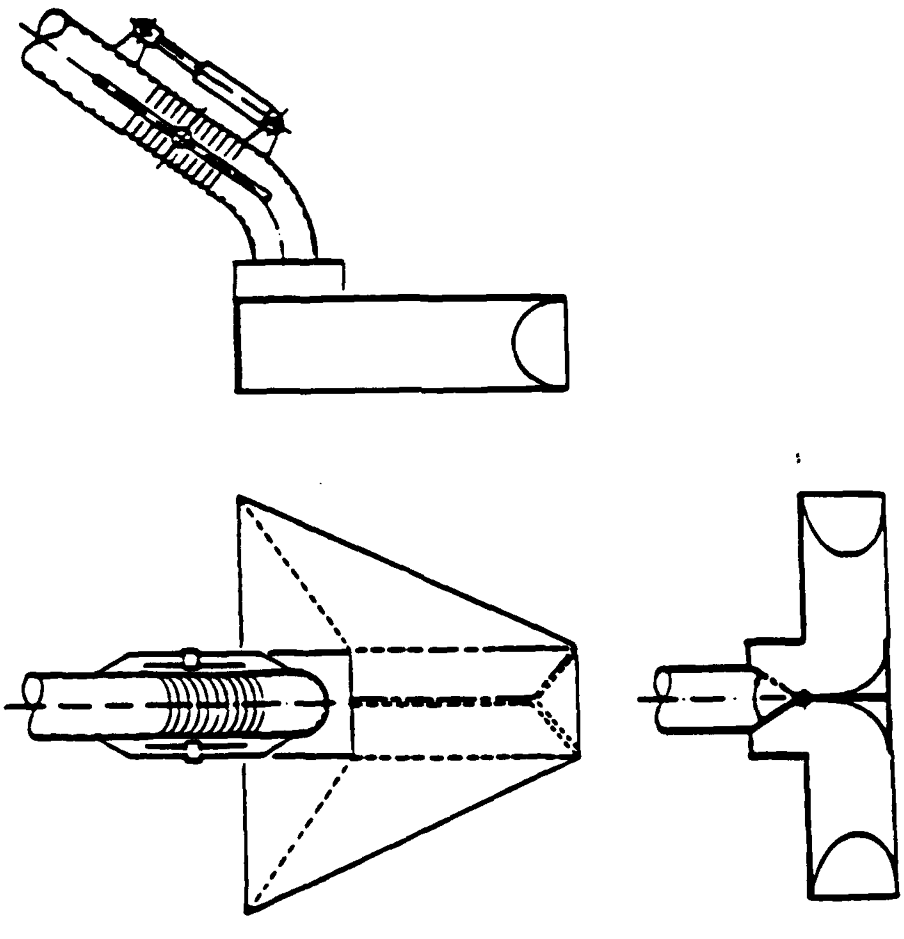
PNEUMA PUMP PNEUMATIC DREDGE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 45



Suction head of Clean-up dredge system



Matchbox head

From: Palermo, 1988

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CLEAN-UP AND MATCHBOX DREDGES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 46

5.3.1.2 Selection of Dredging Equipment

No one dredge type appears suitable to dredge all the contaminated sediments from Onondaga Lake due to the large quantity of sediments, depth of aminated sediments, and clearance restrictions on the Oswego Canal and Canal systems. One solution may be to use two different types of .ges. Due to the large volume of sediments that would need to be removed, .e use of more than one dredge may be desirable to speed up the dredging process.

Of the 11 dredge types discussed in the preceding paragraphs, the clamshell and hopper dredges are not considered feasible alternatives. The clamshell dredge is unacceptable due to the high resuspension rate of sediments while the use of a hopper dredge is not feasible due to the low overhead clearance (19 feet) on the canal system leading into Onondaga Lake from Lake Ontario. The enclosed clamshell dredge has a relatively low sediment resuspension rate, but does cause resuspension when the bucket is dropped into the sediments and does leave an irregular surface bottom. This dredge could be used to remove sediments from both shallow and deep portions of the lake.

The cutterhead, dustpan, and suction hydraulic dredges are all feasible dredges for use on Onondaga Lake. However, due to the vertical clearance restriction on the canal system, only small versions of these dredges are available for use on Onondaga Lake, unless a dredge can be assembled on site. Therefore, without on-site assembly of a large dredge plant, these three dredge types would have limited production rates (up to 100 cubic yards per hour for a cutterhead dredge) and a limited maximum dredging depth (12 feet for the cutterhead dredge). These three dredge types would be restricted to dredging contaminated sediments from shallow areas of the lake. Of the three, the cutterhead can dredge a wider range of sediment material, does not tend to clog as readily as the suction dredge, can pump greater distances and greater elevations than the dustpan dredge, and has been described as the logical selection for controlling sediment resuspension while maintaining efficient production.

The PNEUMA pneumatic dredge has a good production rate (up to 2,600 cubic yards per hour) and can dredge sediments at depths ranging from 12 to in excess of 150 feet at extremely low turbidity levels. The PNEUMA system dismantles easily for transport by truck or air and is available in the United States.

Of the four specialty dredges discussed previously, the refresher system and clean-up dredge are foreign dredges and are not readily available for use in the United States. The matchbox and waterless dredges are both proprietary dredges and have been used for cleanup of sites in the northeastern United States. Each of these four dredges causes very little turbidity and has a relatively high solids content in the dredged slurry.

5.3.1.3 Cost Estimates

Based on preliminary investigations for this reconnaissance report the enclosed clamshell dredge, hydraulic pipeline cutterhead dredge, PNEUMA pump pneumatic dredge, matchbox, and waterless dredges should be considered for removal of contaminated sediments from Onondaga Lake.

Preliminary cost estimates were made for this study to approximate the of removing contaminated sediments from the lake. In developing these ites it was assumed that a hydraulic dredge would be assembled on site to plish the dredging and sediment will be hydraulically placed in the CDF. ...ning, engineering and design, and construction management are included in the cost estimates as well as mobilization and demobilization and a contingency. The cost of dredging the volume of material required to remove sediments containing mercury concentrations greater than or equal to 1.0 ppm, 6.500.000 cubic yards, has been estimated at $61.700,000, based on June 1990 price levels. The cost estimate for dredging sediments containing mercury concentrations of 5.0 ppm or greater is $28,500,000 and involves the removal of 3.000.000 cubic yards of contaminated sediments. The cost of dredging the volume of material required to remove sediments containing mercury concentrations greater than or equal to 10.0 ppm, 2.000,000 cubic yards, has been estimated at $19.100.000. These costs are presented in Table 18.

These cost estimates are subject to change if the quantity of material to be dredged changes, if specialized equipment is required to perform dredging operations and control sediment resuspension, and if costs change from the June 1990 price levels used in preparing the estimates.

5.3.2 Disposal Sites

The volume of excavation required to remove sediment containing mercury concentrations greater than or equal to 1.0 ppm has been estimated at 6.500.000 cubic yards while the volume of excavation required to remove sediment containing mercury concentrations of 5.0 ppm or greater has been estimated at 3.000.000 cubic yards. Approximately 2,000,000 cubic yards of excavation would be required to remove sediment containing mercury in concentrations greater than or equal to 10.0 ppm. Six separate confined disposal facility (CDF) configurations were considered for possible disposal of the sediments (Figure 47). Two locations at the south end of the lake on each side of the Barge Canal Terminal were not investigated in detail due to an apparent lack of disposal capacity, particularly if sediments containing lower mercury concentration are removed. For purposes of identification only, these two potential disposal areas will be identified as the Ley Creek CDF and the Harbor Brook CDF. The four remaining CDFs considered in this report are located at Lakeview Point. Two of these Lakeview Point CDFs appear to have sufficient capacity to contain all the sediment contaminated with greater than or equal to 1.0 ppm mercury. The use of two or more CDFs was not considered due to the desirability to limit encroachment on Onondaga Lake.

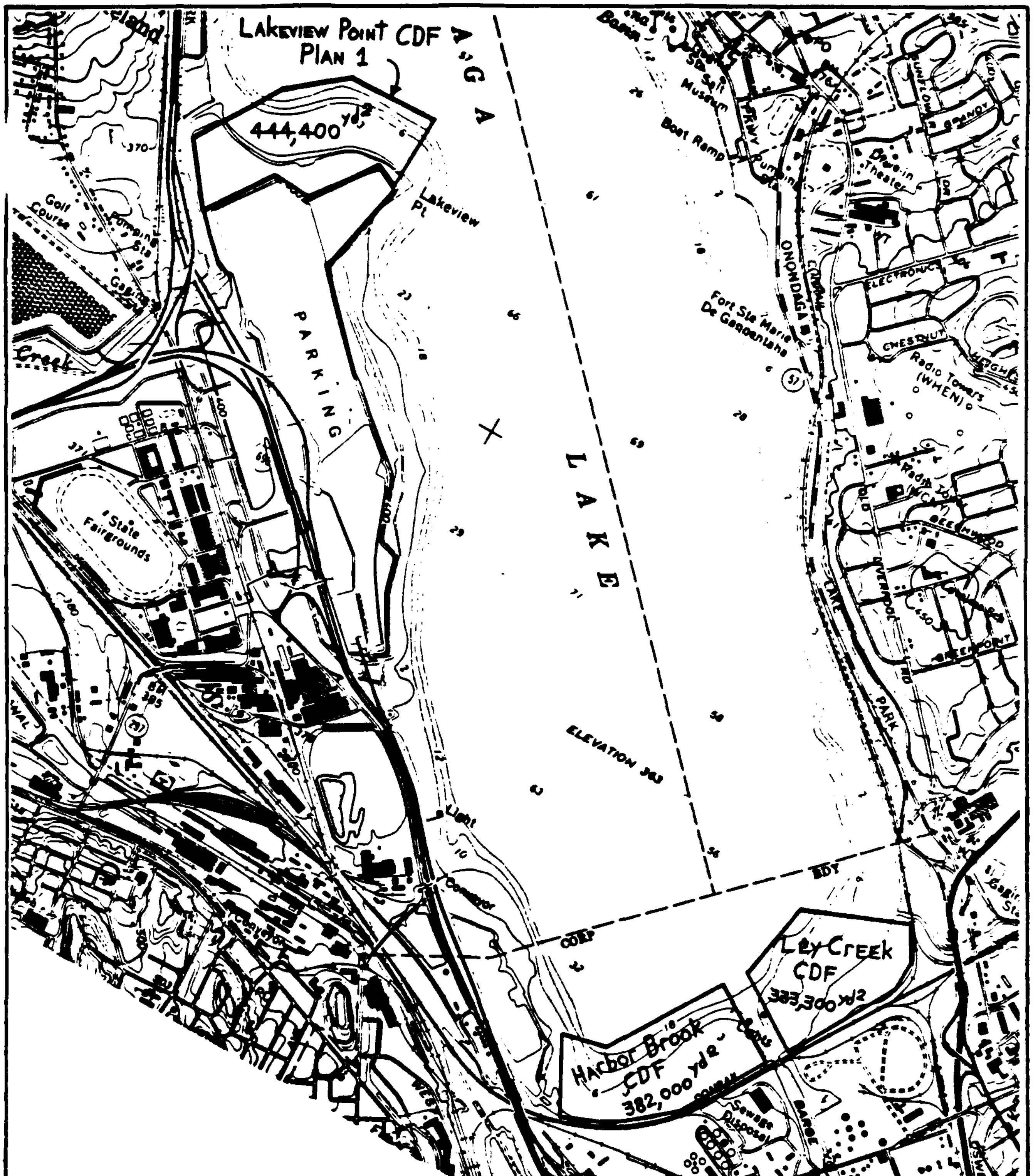
The basic cross section design (coarse fill, side slopes, filter layer), was adapted from a CDF cross section developed for another Buffalo District project. Clay fill was used in the upper portion of the Onondaga Lake cross section since it would be less expensive than the coarse fill. Clay was not used below the anticipated water surface in order to avoid construction difficulties associated with placing clay below water. Crest elevations were selected based on the required CDF capacity. The design of the dike's armor and underlayer protection was based on standard coastal engineering practices.

Table 18 Cost Estimates for Dredging Contaminated Sediments

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
[illegible]ION & [illegible]ION	-	L.S.	-	100,000	25,000	125,000
[illegible] OF SOILS & SLUDGES	6,500,000	C.Y.	6.50	42,250,000	10,562,500	52,812,500
TOTAL CONSTRUCTION COST				42,350,000	10,587,500	52,937,500
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				4,800,000	-	4,800,000
CONSTRUCTION MANAGEMENT				4,000,000	-	4,000,000
TOTAL				$51,150,000	$10,587,500	$61,737,500 SAY $61,700,000

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
MOBILIZATION & DEMOBILIZATION	-	L.S.	-	100,000	25,000	125,000
EXCAVATION OF SOILS & SLUDGES	3,000,000	C.Y.	6.50	19,500,000	4,875,000	24,375,000
TOTAL CONSTRUCTION COST				19,600,000	4,900,000	24,500,000
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				2,200,000	-	2,200,000
CONSTRUCTION MANAGEMENT				1,800,000	-	1,800,000
TOTAL				$23,600,000	$ 4,900,000	$28,500,000

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
MOBILIZATION & DEMOBILIZATION	-	L.S.	-	100,000	25,000	125,000
EXCAVATION OF SOILS & SLUDGES	2,000,000	C.Y.	6.50	13,000,000	3,250,000	16,250,000
TOTAL CONSTRUCTION COST				13,100,000	3,275,000	16,375,000
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				1,480,000	-	1,480,000
CONSTRUCTION MANAGEMENT				1,230,000	-	1,230,000
TOTAL				$15,810,000	$ 3,275,000	$19,085,000 SAY $19,100,000



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISANCE REPORT

LOCATION OF LEY CREEK, HARBOR BROOK AND PLAN 1 CDF ALTERNATIVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 47

5.3.2.1 Ley Creek Confined Disposal Facility (CDF)

The Ley Creek CDF alternative site is located at the south end of Onondaga Lake, between Ley Creek and the Barge Canal Terminal (Figure 47). The area of CDF site located here would be limited by Ley Creek on one side and the canal on the other side as well as by the depth of Onondaga Lake. For this report, it was presumed that the Ley Creek CDF would extend to a maximum water depth of 22 feet, a reasonable working depth for construction of a confined disposal facility. Extending Ley Creek through the disposal facility, to allow the construction of a larger facility, was not considered due to the added costs and problems such a design would involve. It was presumed that the crest elevation of the CDF would be 377 feet (National Geodetic Vertical Datum), or approximately 14 feet above lake level and roughly level with a railroad embankment adjacent to the landward side of this location. With this configuration the Ley Creek CDF alternative would cover an area of approximately 69 acres and have an average sediment height of roughly 15 feet, from 3 feet below to 12 feet above lake level (2 feet below the crest of the CDF). This would give the Ley Creek disposal facility a capacity of approximately 1,665,000 cubic yards which is insufficient to hold the anticipated volume of contaminated sediments.

5.3.2.2 Harbor Brook Confined Disposal Facility (CDF)

The Harbor Brook CDF alternative site is located at the south end of Onondaga Lake, between Harbor Brook and the Barge Canal Terminal (Figure 47). A CDF site at this location would be limited in size by Harbor Brook on one side and the canal on the other side, as well as by the depth of Onondaga Lake. It was presumed that the Harbor Brook CDF would extend to a maximum water depth of 22 feet. Extending Harbor Brook through the disposal facility to allow the construction of a larger facility was not considered due to the added cost and problems that would be involved. The crest elevation of this CDF was presumed to be at elevation 377 feet, approximately 14 feet above lake level and roughly even with the crest of the railroad embankment on the landward side of this location. With this configuration the Harbor Brook CDF alternative would cover an area of approximately 79 acres and have an average sediment height of roughly 18 feet, from 6 feet below to 12 feet above water level (2 feet below the dike crest). This would give the Harbor Brook CDF a capacity of approximately 2,300,000 cubic yards which is insufficient to hold the anticipated volume of contaminated sediments unless only sediments with mercury concentrations of 10.0 ppm or greater are removed.

5.3.2.3 Lakeview Point Confined Disposal Facilities (CDFs)

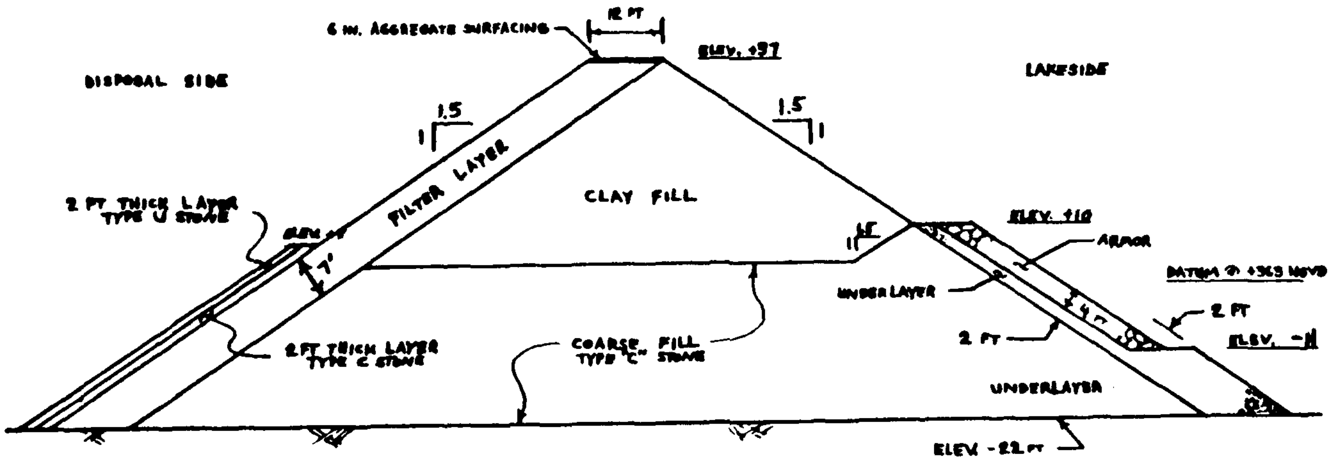
The Lakeview Point CDF sites are located on the west side of Onondaga Lake, adjacent to the Solvay Process Waste Beds No. 1-8, located between the Onondaga Lake shoreline and Interstate 690. The waste beds extend roughly 1.5 miles along the shoreline and have a maximum width of approximately 0.5 mile (Allied-Signal, Inc., 1990). These waste beds were in use by Allied in 1926 through 1944 and occupy an area of roughly 315 acres. Waste beds were constructed to a peak elevation of approximately 420 feet or roughly 57 feet above lake level. Nine Mile Creek empties into Onondaga Lake at the north end of the waste beds.

All four of the Lakeview Point CDF sites are located at the north end of the waste beds. It was presumed that the first Lakeview Point CDF (Plan 1) would extend to a maximum water depth of 22 feet and would be shaped to avoid

-ference with Onondaga Creek (Figure 47). The crest of this CDF was -ed to be at elevation 400 feet; approximately 37 feet above lake level. ng in a maximum dike height of 59 feet. The perimeter of this facility ,e roughly 9,200 feet in length with approximately 4,300 feet of this in Onondaga Lake and 3,100 feet adjacent to the Solvay Process Waste Beds. Typical cross sections of this CDF alternative are shown in Figures 48 and 49. Core stone would be used in the construction of the underwater portion of the dike while clay fill would be used in the construction of the above water portion of the dike. Armor stone and underlayer stone would be placed on the lakeside slope to protect the dike from wave attack while a 7-foot layer of filter material would be placed on the disposal side of the dike to ensure the containment of contaminated sediments while allowing the passage of water collected as part of the dredging process. Portions of this facility would require water based construction equipment while other portions could be constructed using land based equipment.

With this configuration the Lakeview Point CDF alternative would cover an area of approximately 92 acres and have an average sediment height of roughly 36 feet when full, from 1 foot below to 35 feet above water level. This would give the CDF a capacity of approximately 5,300,000 cubic yards which appears to be sufficient to hold all of the contaminated sediment that may be dredged. After dredged material is placed within a contaminant area, it undergoes sedimentation and self-weight consolidation resulting in gains in storage capacity (Department of the Army, 1983). In addition, the placement of dredged material imposes a loading on the containment area foundation and additional capacity may result due to consolidation of compressible foundation soils. If a conservative figure of 0.8 is used to relate in-place sediment volume to final CDF sediment volume (In-place Volume x 0.8 = Final CDF Volume) all 6,500,000 cubic yards of in-place sediment contaminated with greater than or equal to 1.0 ppm mercury could be contained in the Lakeview Point CDF.

A second Lakeview Point CDF (Plan 2) was also considered (Figure 50). This CDF would extend to a maximum water depth of 6 feet and also would be shaped to avoid interference with Onondaga Creek. Crest elevation of this CDF was presumed to be at elevation 420 feet, approximately 57 feet above lake level. This would make the CDF crest level with the adjacent waste beds and result in a maximum dike height of 63 feet. This alternative would encroach less on Onondaga Lake while resulting in a slightly larger capacity than the previously discussed Lakeview Point CDF alternative. While the perimeter of this CDF would be roughly 8,900 feet in length only 3,700 feet of this would be in water. Approximately 3,100 feet of this facility would be adjacent to Solvay Process Waste Beds resulting in a much smaller dike section relative to the water portion of the structure. Typical cross sections of this CDF alternative are shown in Figures 51 and 52. Core stone would be used in the construction of the underwater portion of the dike while clay fill would be used in the construction of the above water portion of the dike. Armor stone and underlayer stone would be placed on the lakeside slope to protect the dike from wave attack while a 7-foot layer of filter material would be placed on the disposal side to ensure the containment of contaminated sediments while allowing the passage of water. It is likely that this facility could be built with the use of land based construction equipment only, not requiring the use of water based equipment.



NOTES:

1. ARMOR AND UNDERLAYER STONE SIZED ASSUMING SP. GR. = 2.6
   ARMOR: 650 lb TO 1900 lb, A STONE
   UNDERLAYER: 40 lb TO 140 lb, U STONE
2. TYPE "C": WELL-GRADED 1 IN TO 6 IN

SCALE: 1 IN. = 30 FT

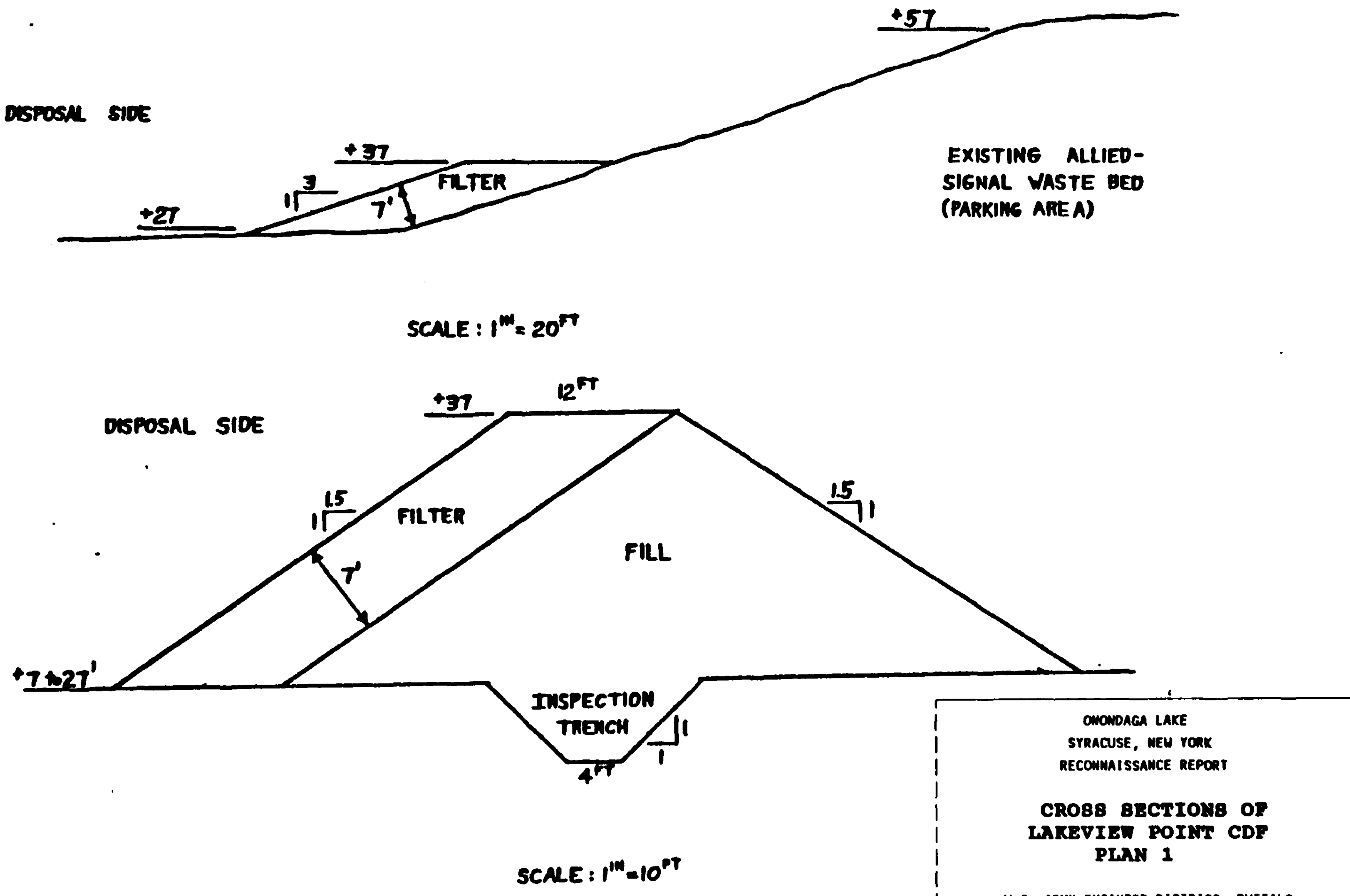
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CROSS SECTION OF LAKEVIEW POINT CDF PLAN 1

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 48

Figure 48

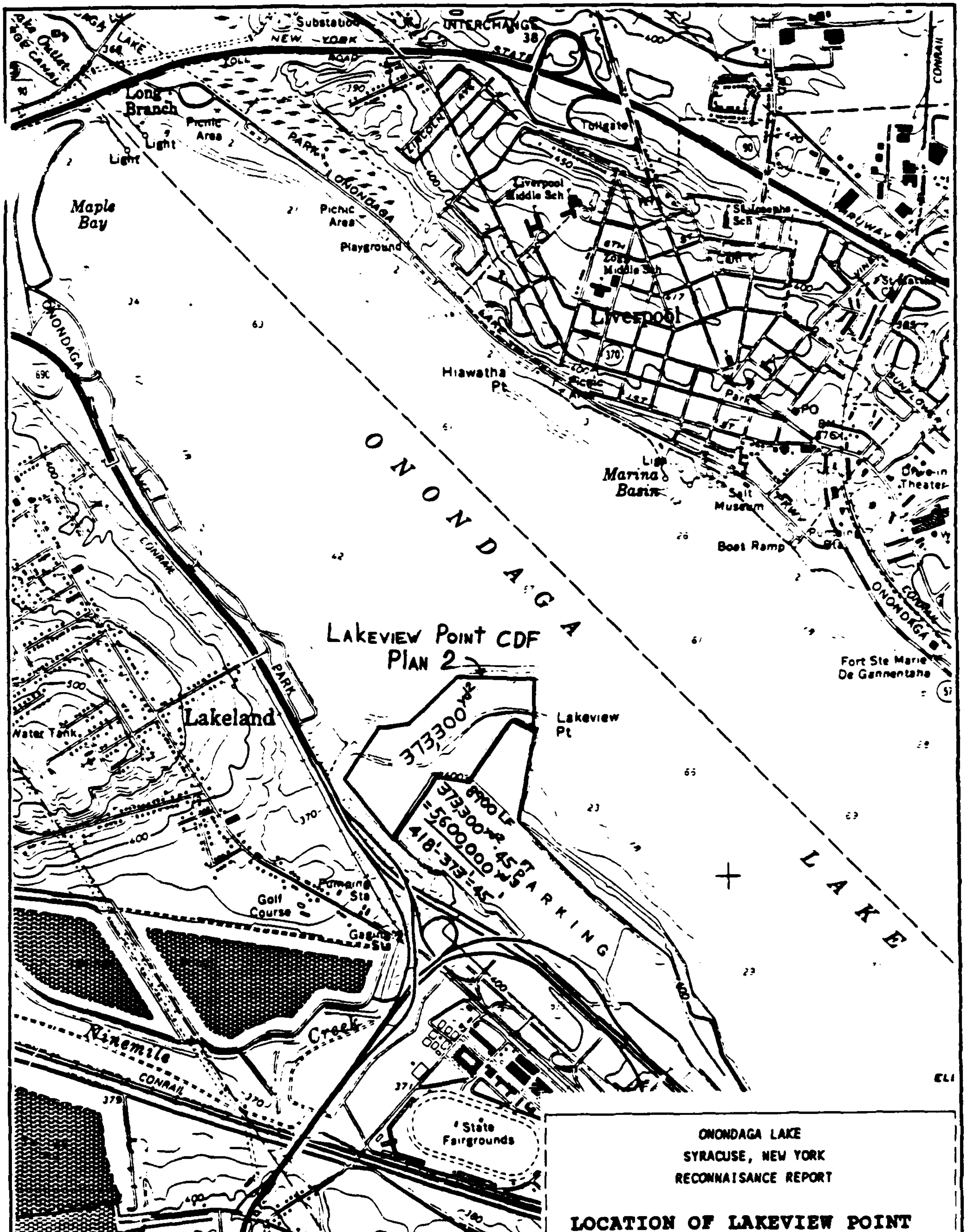


ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CROSS SECTIONS OF LAKEVIEW POINT CDF PLAN 1

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 49



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISANCE REPORT

LOCATION OF LAKEVIEW POINT CDF PLAN 2

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 50

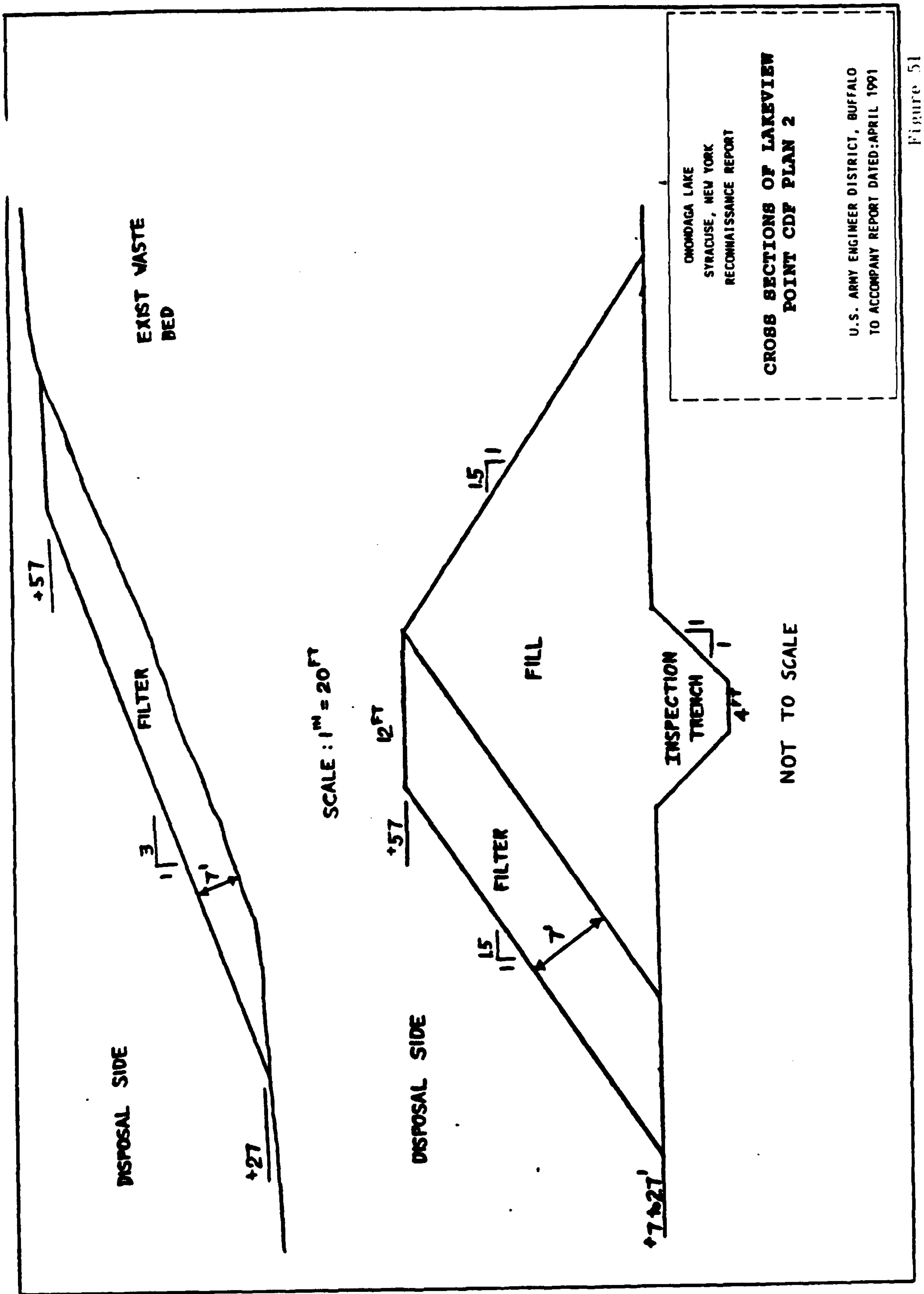
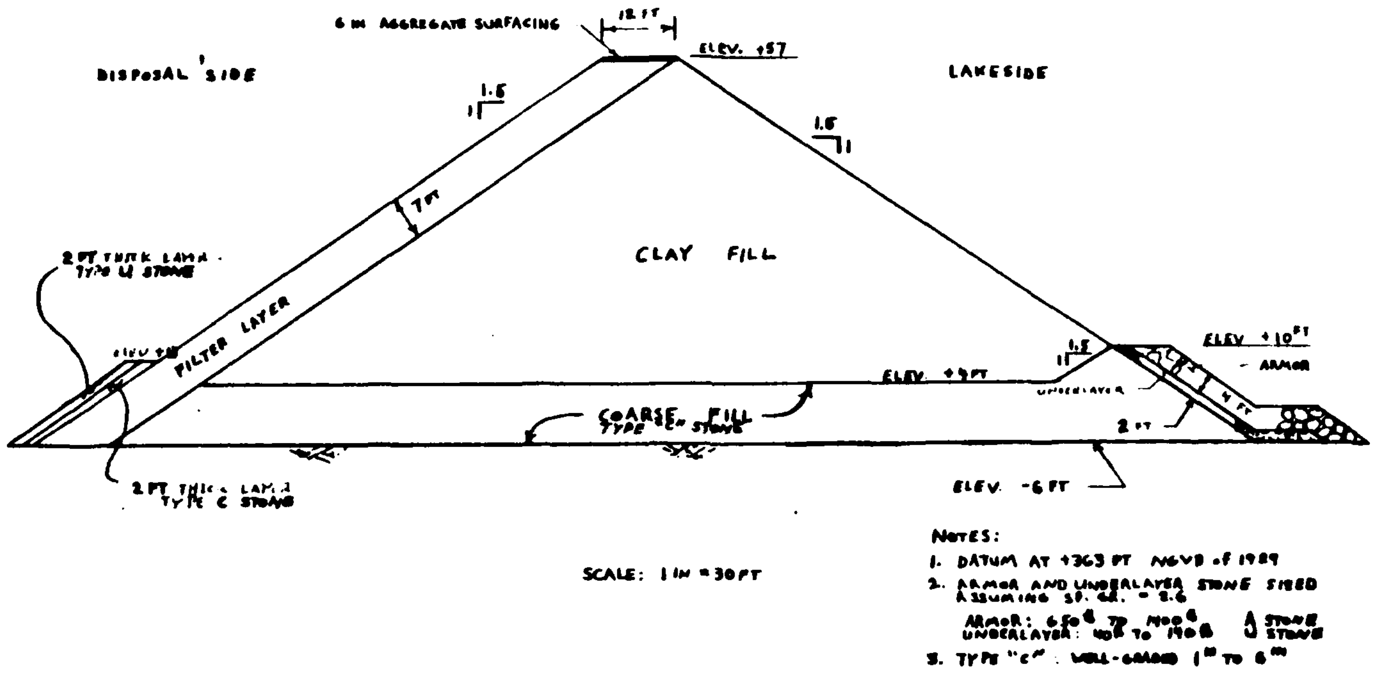


Figure 51

Figure 51



ONONDAGA LAKE

SYRACUSE, NEW YORK

RECONNAISSANCE REPORT

CROSS SECTION OF LAKEVIEW POINT CDF PLAN 2

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 52

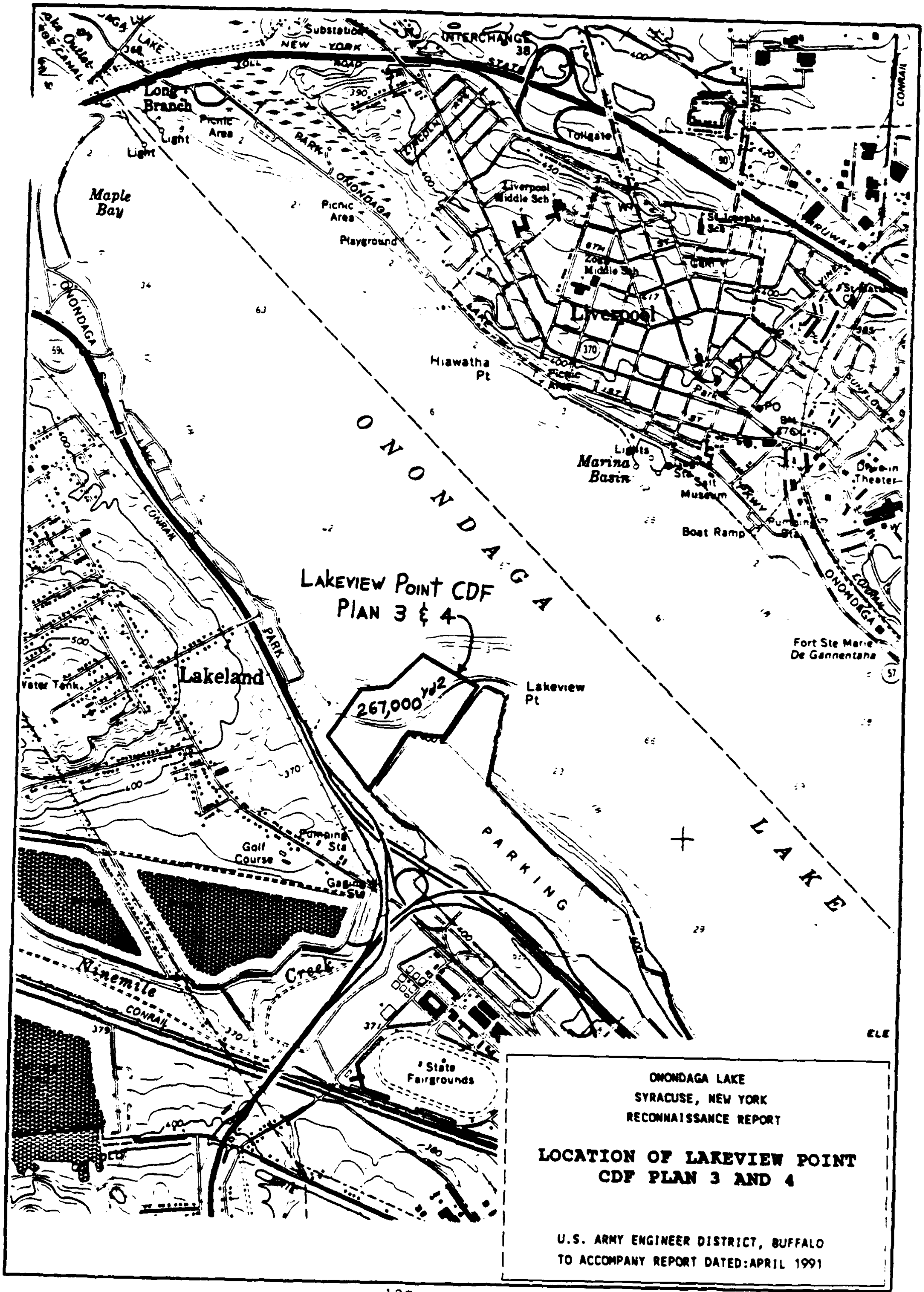
Figure 52

With this configuration the Lakeview Point CDF alternative would cover an area of approximately 77 acres and have an average sediment height when full roughly 45 feet, from 10 feet to 55 feet above water level. This would the CDF a capacity of approximately 5,600,000 cubic yards which appears sufficient to hold all of the contaminated sediment that may be dredged. discussed previously, self-weight consolidation of the dredged material and consolidation of compressible foundation soils under loading imposed by placement of dredged material results in gains in storage capacity. A conservative value to relate in-place sediment volume to final CDF sediment volume is 0.8 (In-place Volume x 0.8 = Final CDF Volume). Using this factor, the above CDF configuration appears adequate to contain all the lake sediment contaminated with greater than or equal to 1.0 ppm mercury.

Advantages of this Lakeview Point configuration over the previously discussed Lakeview Point facility include; (1) less infringement on Onondaga Lake, (2) smaller surface area occupied by the facility, (3) slightly larger capacity, and (4) ease of construction using only land based equipment. However, this configuration may be less appealing due to its higher crest elevation.

The third and fourth Lakeview Point CDF alternatives were investigated for possible containment of small quantities of contaminated sediments. Both of these alternatives would extend to a maximum water depth of 6 feet and would be shaped to avoid interference with Onondaga Creek (Figure 53). The crest elevation of the Plan 3 CDF was presumed to be at elevation 400 feet, approximately 37 feet above lake level, resulting in a maximum dike height of 43 feet and a capacity of 2,400,000 cubic yards. This alternative would encroach less on Onondaga Lake than the two previously discussed Lakeview Point CDFs. The perimeter of this CDF would be roughly 7,200 feet with approximately 2,700 feet of this in Onondaga Lake. Approximately 2,800 feet of the CDF perimeter would be adjacent to the Solvay Process Waste Beds, resulting in a much smaller dike section relative to the water portion of the structure. Typical cross sections of this CDF alternative are shown in Figures 54 through 56. Similar to the previously discussed CDF alternatives, core stone would be used in the construction of the underwater portion of the dike, while clay fill would be used in the construction of the above water portion of the dike. Armor stone and underlayer stone would be placed on the lakeside slope to protect the dike from wave attack while a 7 foot thick layer of filter material would be placed on the disposal side to ensure the containment of contaminated sediments while allowing the passage of water. It is likely that this facility could be built with land based construction equipment.

With this configuration the Lakeview Point CDF alternative would cover an area of approximately 55 acres and have an average sediment height when full of roughly 27 feet, from 7 feet to 34 feet above water level. This would give the facility a capacity of approximately 2,400,000 cubic yards which appears to be sufficient to hold all of the sediments contaminated with greater than or equal to 5 ppm mercury. As previously discussed, self-weight consolidation of the dredged material and consolidation of compressible foundation soils under loading imposed by placement of dredged material results in gains in storage capacity. A conservative value to relate in-place sediment volume to

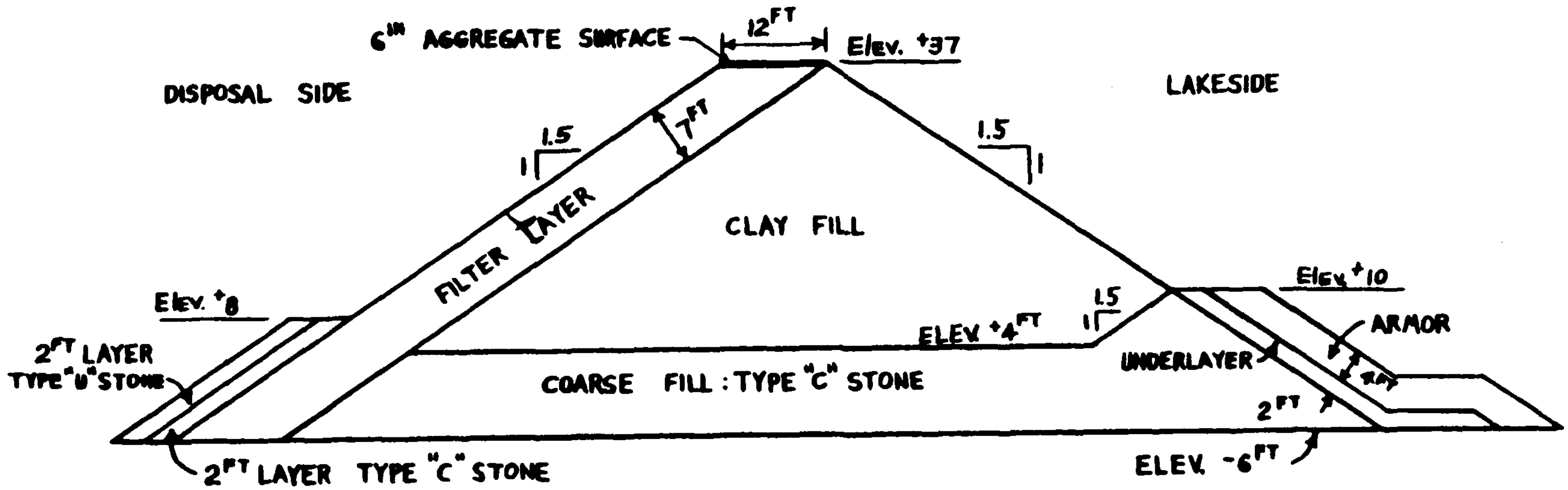


ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

LOCATION OF LAKEVIEW POINT CDF PLAN 3 AND 4

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 53



SCALE: $1^{IN} = 20^{FT}$
APPROX. 2700^{LF}

NOTES:
1. DATUM = 363^{FT} NGVD OF 1929
2. ARMOR AND UNDERLAYER STONE SIZED ASSUMING SP. GR. = 2.6
   ARMOR : 650# to 1400# A STONE
   UNDERLAYER : 40# to 140# U STONE
3. TYPE "C" WELL GRADED 1^{IN} - 6^{IN}

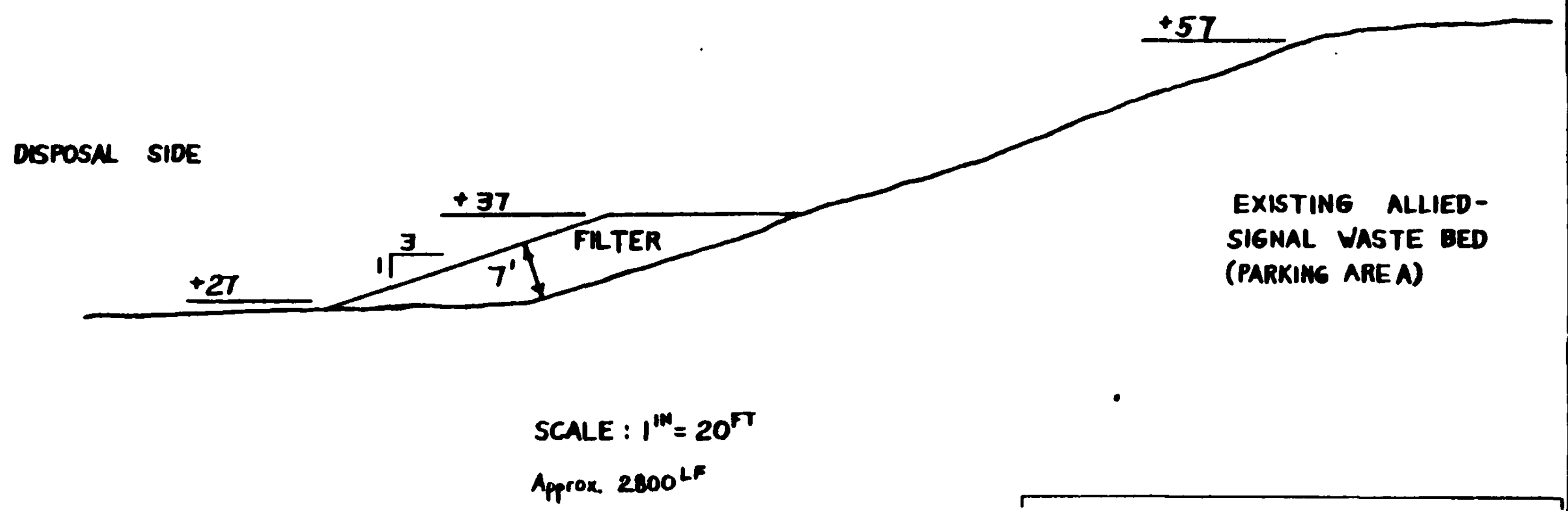
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CROSS SECTION OF LAKEVIEW POINT CDF PLAN 3

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 54

Figure 54



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CROSS SECTION OF LAKEVIEW POINT CDF PLAN 3

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 55

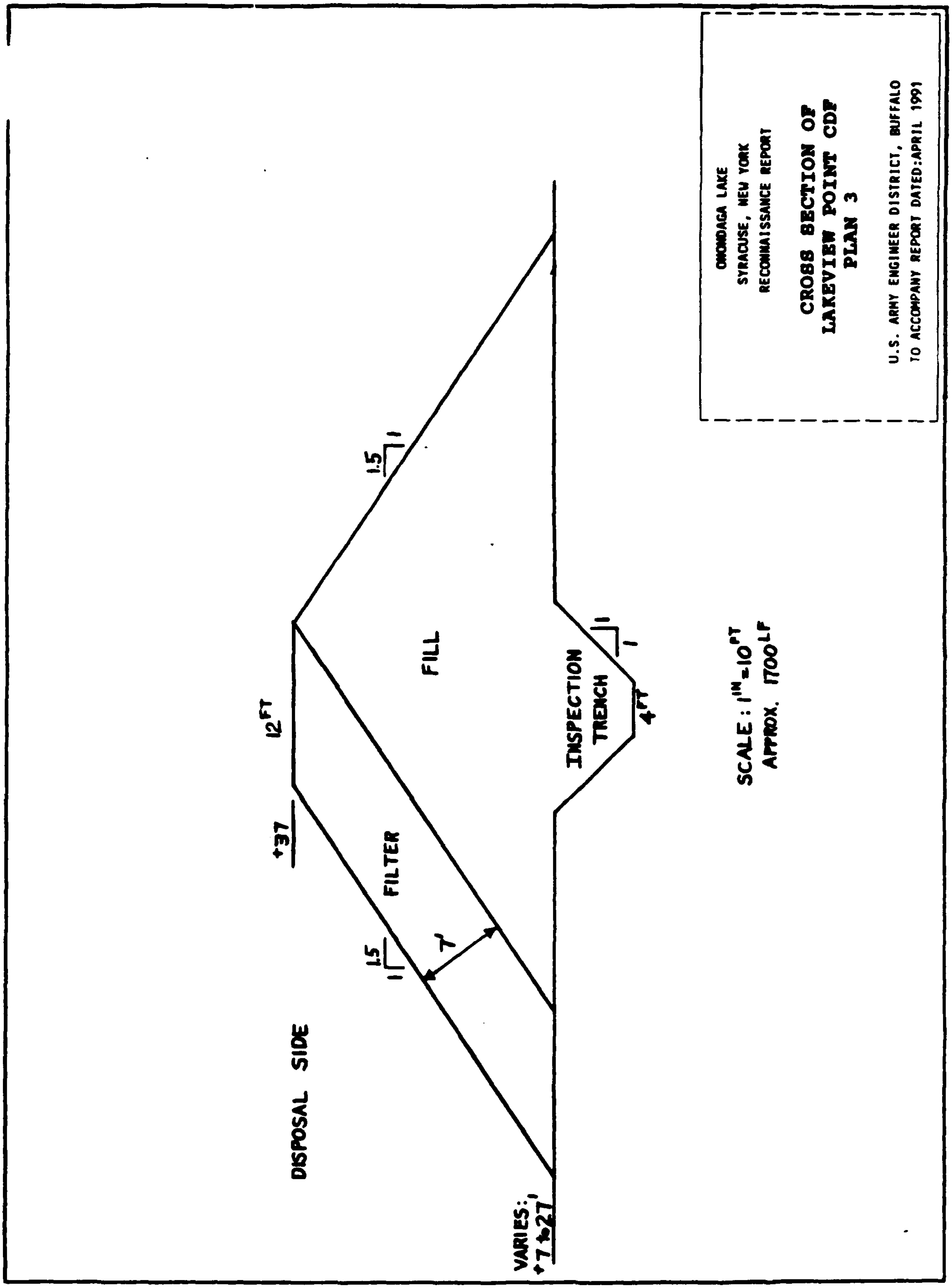


Figure 56

Figure 56

final CDF sediment volume is 0.8; In-place Volume x 0.8 = Final CDF Volume. U[illegible] this factor, the above CDF configuration appears adequate to contain all [illegible]ake sediment contaminated with greater than or equal to 5 ppm mercury, [illegible]ximately 3,000,000 cubic yards of material.

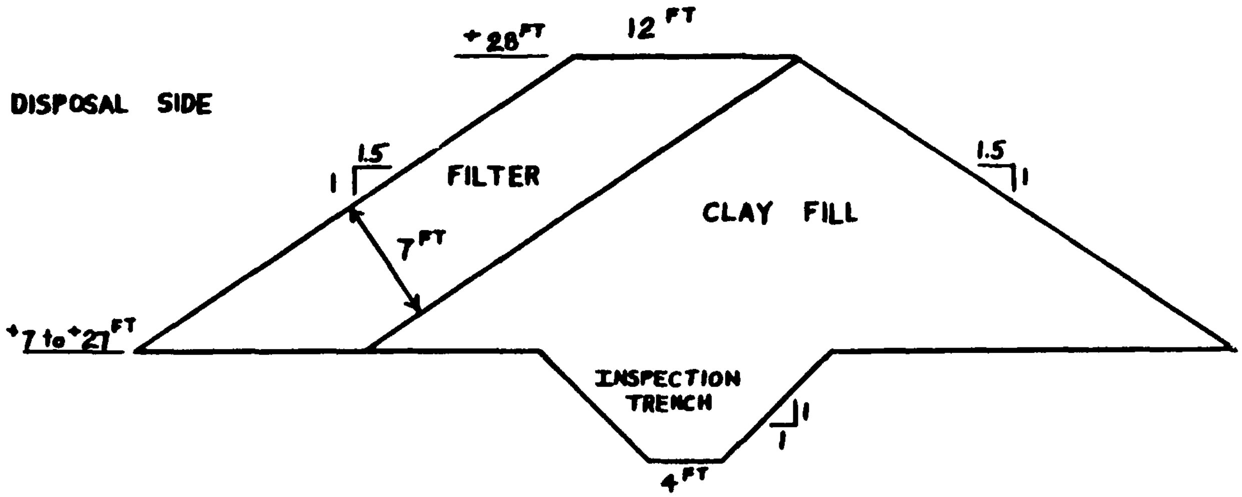
Confined Disposal Facility Plan 4 at Lakeview Point has the same plan view as Plan 3 and would also extend to a maximum water depth of 6 feet. The crest elevation for Plan 4 is 391 feet, approximately 28 feet above lake level, resulting in a maximum dike height of 34 feet and a capacity of 1,600,000 cubic yards. Typical cross sections of this CDF alternative are shown in Figures 57 and 58. Core stone would again be used in the construction of the underwater portion of the dike while clay fill would be used in the construction of the above water portion of the dike. Armor stone and underlayer stone would again be placed on the lakeside slope to protect the dike from wave attack while a 7-foot layer of filter material would be placed on the disposal side to ensure the containment of contaminated sediments while allowing the passage of water.

This plan would cover an area of approximately 55 acres and have an average sediment height when full of roughly 18 feet, from 7 feet to 25 feet above water level. This would give the CDF a capacity of approximately 1,600,000 cubic yards. Using the value of 0.8 to relate in-place sediment volume to final CDF sediment volume, this CDF appears adequate to contain all the Onondaga Lake sediments contaminated with greater than or equal to 10 ppm mercury, approximately 2,000,000 cubic yards of material.

5.3.2.4 Cost Estimates

Preliminary cost estimates based on June 1990 price levels were made for this reconnaissance report to approximate the cost of constructing the four confined disposal facilities at the Lakeview Point site. In making these estimates it was anticipated that clay borrow would be available within 5 miles of the construction site and sand borrow would be available within 10 miles of the construction site. Stone products required for construction will be obtained from quarries in the region. Planning, engineering and design, and construction management costs are also included in the estimates, as well as a contingency on the construction costs. The cost of constructing Plan 1, to hold 6,500,000 cubic yards of sediment in up to 22 feet of water, has been estimated at $63,500,000, based on June 1990 price levels. The cost of constructing Plan 2, to contain 6,500,000 cubic yards of sediments in up to 6 feet of water, has been estimated at $50,700,000. Construction of the Plan 3 CDF to contain 3,000,000 cubic yards of sediments has been estimated to cost $20,900,000, while the cost of Plan 4 to contain 2,000,000 cubic yards of sediments has been estimated at $17,500,000. The detailed cost estimate is shown in Table 19.

These cost estimates are preliminary and are subject to change based on the final CDF design, including its location, size, and cross section as well as the availability of construction materials and other factors affecting costs.



SCALE: 1 IN = 10 FT
APPROX. 4500 LF

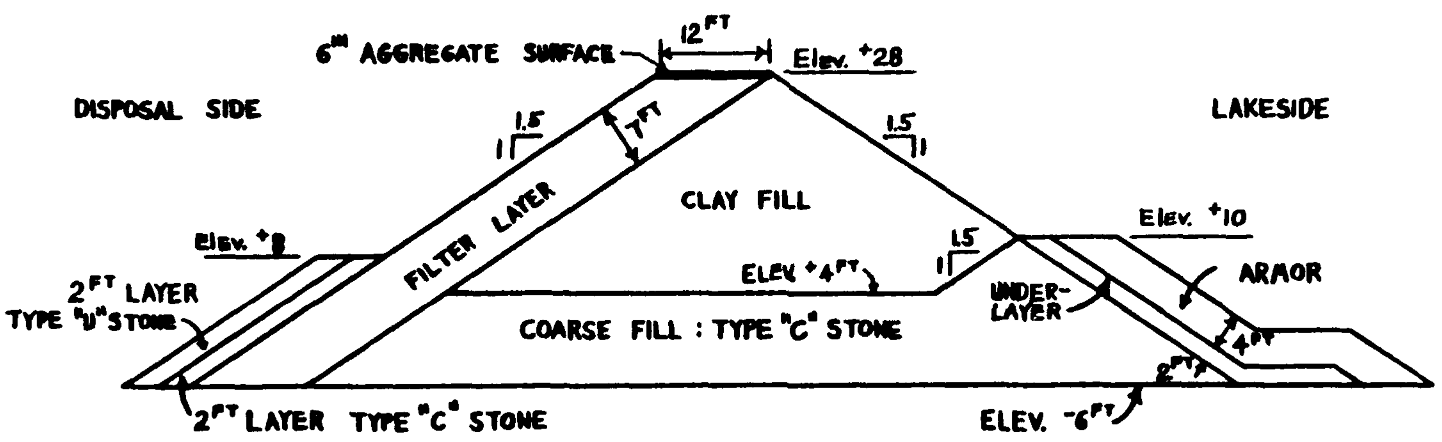
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CROSS SECTION OF LAKEVIEW POINT CDF PLAN 4

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 57

Figure 57



SCALE : $1^{IN} = 20^{FT}$

APPROX. 2700^{LF}

NOTES:

1. DATUM = 363^{FT} NGVD OF 1929
2. ARMOR AND UNDERLAYER STONE SIZED ASSUMING SP. GR. =2.6

   ARMOR : 650^{lb} to 1400^{lb} A STONE

   UNDERLAYER : 40^{lb} to 140^{lb} U STONE
3. TYPE "C" WELL GRADED 1^{IN} - 6^{IN}

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

CROSS SECTION OF LAKEVIEW POINT CDF PLAN 4

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 58

Figure 58

Table 19 Estimates for Construction of Confined Disposal Facilties

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
DISPOSAL AREA (PLAN 1)						
6" AGGREGATE SURFACING	7,800	S.Y.	6.00	46,800	11,700	58,500
ARMOR STONE (650#-1,400#)	30,400	TON	49.40	1,501,760	375,440	1,877,200
UNDERLAYER STONE (40#-140#)	71,400	TON	42.25	3,016,650	754,163	3,770,813
TYPE "C" STONE (1" - 6")	798,000	TON	36.50	29,127,000	7,281,750	36,408,750
FILTER STONE (#200-6")	191,800	TON	36.50	7,000,700	1,750,175	8,750,875
CLAY EMBANKMENT	290,000	C.Y.	10.00	2,900,000	725,000	3,625,000
TOTAL CONSTRUCTION COST				43,592,910	10,898,228	54,491,138
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				4,930,000	-	4,930,000
CONSTRUCTION MANAGEMENT				4,080,000	-	4,080,000
TOTAL				$52,602,910	$10,898,228	$63,501,138 SAY $63,500,000

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
DISPOSAL AREA (PLAN 2)						
6" AGGREGATE SURFACING	6,900	S.Y.	6.00	41,400	10,350	51,750
ARMOR STONE (650#-1,400#)	27,700	TON	49.40	1,368,380	342,095	1,710,475
UNDERLAYER STONE (40#-140#)	23,800	TON	42.25	1,005,550	251,388	1,256,938
TYPE "C" STONE (1" - 6")	350,000	TON	36.50	12,775,000	3,193,750	15,968,750
FILTER STONE (#200-6")	322,000	TON	36.50	11,753,000	2,938,250	14,691,250
CLAY EMBANKMENT	785,000	C.Y.	10.00	7,850,000	1,962,500	9,812,500
TOTAL CONSTRUCTION COST				34,793,330	8,698,333	43,491,663
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				3,950,000	-	3,950,000
CONSTRUCTION MANAGEMENT				3,260,000	-	3,260,000
TOTAL				$42,003,330	$ 8,698,333	$50,701,663 SAY $50,700,000

(Cont'd) Table 19

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
DISPOSAL AREA (PLAN 3)						
6" AGGREGATE SURFACING	12,150	S.Y.	6.00	72,900	18,225	91,125
ARMOR STONE (650#-1,400#)	20,100	TON	49.40	992,940	248,235	1,241,175
UNDERLAYER STONE (40#-140#)	17,650	TON	42.25	745,713	186,428	932,141
TYPE "C" STONE (1" - 6")	172,800	TON	36.50	6,307,200	1,576,800	7,884,000
FILTER STONE (#200-6")	112,700	TON	36.50	4,113,550	1,028,388	5,141,938
CLAY EMBANKMENT	208,000	C.Y.	10.00	2,080,000	520,000	2,600,000
TOTAL CONSTRUCTION COST				14,312,303	3,578,076	17,890,378
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				1,620,000	-	1,620,000
CONSTRUCTION MANAGEMENT				1,340,000	-	1,340,000
TOTAL				$17,272,303	$ 3,578,076	$20,850,378 SAY $20,900,000

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
DISPOSAL AREA (PLAN 4)						
6" AGGREGATE SURFACING	9,600	S.Y.	6.00	57,600	14,400	72,000
ARMOR STONE (650#-1,400#)	20,100	TON	49.40	992,940	248,235	1,241,175
UNDERLAYER STONE (40#-140#)	17,650	TON	42.25	745,713	186,428	932,141
TYPE "C" STONE (1" - 6")	136,400	TON	36.50	4,978,600	1,244,650	6,223,250
FILTER STONE (#200-6")	102,100	TON	36.50	3,726,650	931,663	4,658,313
CLAY EMBANKMENT	150,000	C.Y.	10.00	1,500,000	375,000	1,875,000
TOTAL CONSTRUCTION COST				12,001,503	3,000,376	15,001,878
REAL ESTATE: LANDS, EASEMENTS & RIGHTS OF WAY ADMINISTRATION						
PLANNING, ENGINEERING & DESIGN				1,360,000	-	1,360,000
CONSTRUCTION MANAGEMENT				1,120,000	-	1,120,000
TOTAL				$14,481,503	$ 3,000,376	$17,481,878 SAY $17,500,000

5.3.3 Solidification/Stabilization

The dredged sediments may be solidified/stabilized in the confined disposal facility. The term solidification describes the elimination of free water from a semi-solid by addition of a setting agent such as Portland cement, lime, flyash, kiln dust, and slag (International Joint Commission, 1988). Solidification can result in the physical stabilization of the contaminated sediments, the chemical immobilization of the contaminants, or both. Physical stabilization refers to processes aimed at optimizing certain engineering properties such as bearing capacity while chemical stabilization refers to the minimization of contaminant leachability and solubility. The bulk of solidification technologies currently under evaluation require the removal, and in some cases, dewatering of contaminated sediments. Below is a description of solidification/stabilization methods taken from WES report "Review of Removal, Containment, and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes" (Averett, Perry, Torrey, 1989).

Many solidification/stabilization processes incorporate Portland cement as the binding agent. Pozzolanic products such as flyash are frequently added to Portland cement to react with any free calcium hydroxide, and thus improve the strength, handling characteristics, and chemical resistance of the concrete-like product. Cement processes reduce the mobility of heavy metals due to their conversion to insoluble hydroxides or carbonates because of the elevated pH of cement. Sorbents and other additives such as soluble silicates, clays, emulsifiers, carbon, zeolitic materials, cellulosic sorbents, and lime are often mixed with cement to decrease the loss of specific contaminants and improve performance. This process, one of the more versatile and adaptable solidification/stabilization methods, results in a product with exceptional strength and durability, and retains contaminated materials very effectively.

5.3.3.1 Lime-Based Pozzolan Solidification/Stabilization

Pozzolanic materials are described as those that set to a solid mass when mixed with hydrated lime. Pozzolons all contain silicic acid and frequently aluminum oxide. Solidification/stabilization of contaminated materials using lime and pozzolans requires that the material be mixed with a carefully selected, reactive pozzolonic additive to a pasty consistency and subsequently blended with hydrated lime. The resulting moist material may be packed or compressed into molds or placed into a disposal site and compacted. The pozzolonic material typically used for solidification/stabilization is bituminous coal or subbituminous coal flyash. The process is less expensive but produces a less durable product and has greater contaminant leachability when compared to cement based processes. Lime/flyash solidification/stabilization of dredged material was evaluated in laboratory studies for sediment from Everett Bay and Indiana Harbor. Results for leachate testing of several heavy metals were mixed.

5.3.3.2 Mixing Considerations

The mixing of the setting agent with dredged material can be accomplished by placing the sediment into a mixing plant or by mixing in-situ in a disposal area or staging area after the sediments have been dredged. In-situ mixing

accomplished with conventional construction equipment is potentially best suited for mixing dewatered sediments with large quantities of low-reacting setting agents. Mixing efficiency has not been accurately assessed at field-scale. Equipment could be used to inject the setting agents into contaminated materials and mix the two while traveling the perimeter of the mixing area. Once this treated material is capable of supporting the injection carrier, the carrier could be positioned on top of the solidified material and a second pass initiated. Plant mixing is justified when large amounts of dredged sediments require treatment. The plant would consist of mixing and treatment units (International Joint Commission, 1988).

5.3.3.3 Feasibility of Solidification Processes

Further evaluation is required prior to full-scale implementation of solidification processes. The potential for chemicals to interfere with the solidification process has been established (International Joint Commission, 1988). Therefore, any study exploring the use of solidification at Onondaga Lake will require laboratory testing of setting agents and their interactions with the contaminated sediments. Field testing examining mixing efficiency and long term stability of the treated material should also be conducted.

5.3.3.4 Cost Estimates

Bench scale studies conducted by Associated Chemical and Environment Services and Chem Fix Technologies with contaminated sediments from Foundry Cove resulted in cost estimates for the treatment of 64,500 cubic yards of $50-$75 per cubic yard and $45-$50 per cubic yard, respectively (International Joint Commission, 1988). The estimates do not include removal or disposal costs. Costs are affected both by the selected implementation strategy, costs related to additives, and volume requirements. For example, Portland cement solidification results in a highly physically stable product; whereas, less expensive agents produce a solidification product with much lower physical stability as measured by unconfined strength. Similarly, the use of high cost additives result in a significantly more rapid set.

Preliminary cost estimates for this reconnaissance report were developed for the solidification/stabilization process. Since this is a relatively new technology for the treatment of contaminated sediment and has not been used on a project of this magnitude very little actual cost data are available. Therefore, a range of estimates were prepared for the solidification/ stabilization treatment of contaminated sediments at a staging or disposal area after dredging. These estimates were made based on unit costs of $50-$80 per cubic yard and include planning, engineering and design, and construction management costs. The cost estimate for treating the 6,500,000 cubic yards of sediment contaminated with 1.0 ppm mercury or greater ranges from $325,000,000 to $520,000,000 ($50/cy x 6,500,000 cy to $80/cy x 6,500,000 cy). The estimate for treating the 3,000,000 cubic yards of sediment contaminated with 5.0 ppm mercury or greater ranges from $150,000,000 to $240,000,000. The cost estimate for treating the 2,000,000 cubic yards of sediment contaminated with 10.0 ppm mercury or greater ranges from $100,000,000 to $160,000,000. These estimates are for the solidification/stabilization treatment only and do not include the cost of dredging or disposal. The detailed cost estimate is shown in Table 20.

Table 20 Cost Estimates for Solidification/Stabilization

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1 PPM Mercury Solidification/Stabilization	6,500,000	C.Y.	50.00 to 80.00	$325,000,000 to $520,000,000
5 PPM Mercury Solidification/Stabilization	3,000,000	C.Y.	50.00 to 80.00	$150,000,000 to $240,000,000
10 PPM Mercury Solidification/Stabilization	2,000,000	C.Y.	50.00 to 80.00	$100,000,000 to $160,000,000

5.3.4 Capping

A disposal alternative considered for the contaminated sediments in Onondaga Lake was subaquatic burial. This option involves the capping of contaminated sediments with cleaner borrow material. The capping concept is a controlled, accurate, subaqueous placement of contaminated dredged material.and sequestering of the contaminated material from the aquatic environment by some type of covering or cap (Department of the Army, 1987). Variations in techniques and equipment produce different configurations. Level bottom capping places the material on the existing natural bottom in a discrete mound. Capping material is then applied over the mound to ensure adequate coverage. Contained aquatic disposal (CAD) is the confinement of material through the use of an existing depression, preexcavation of a disposal cell, or construction of submerged dikes or berms to provide more lateral control of sediments. A CAD site is an engineered structure whose successful performance depends on proper design and care during construction.

The contaminated sediments can be collected, placed in a smaller area, and capped in order to achieve isolation. When relocating contaminated sediments it is normally desirable to minimize the size of the placement through precise deposition. Deposition is controlled by careful selection and operation of the dredging equipment. Placement of the dredged material is complicated by the quantities of material involved, the density of the material, the difficulty of positioning equipment, and the lack of visual contact with the deposition site. Precise placement of materials can be accomplished with good navigation control of the depositing ship and the maintenance of a relatively consolidated material mass through mechanical dredging or the fitting of low velocity diffusers on the discharge ends of hydraulic pipelines.

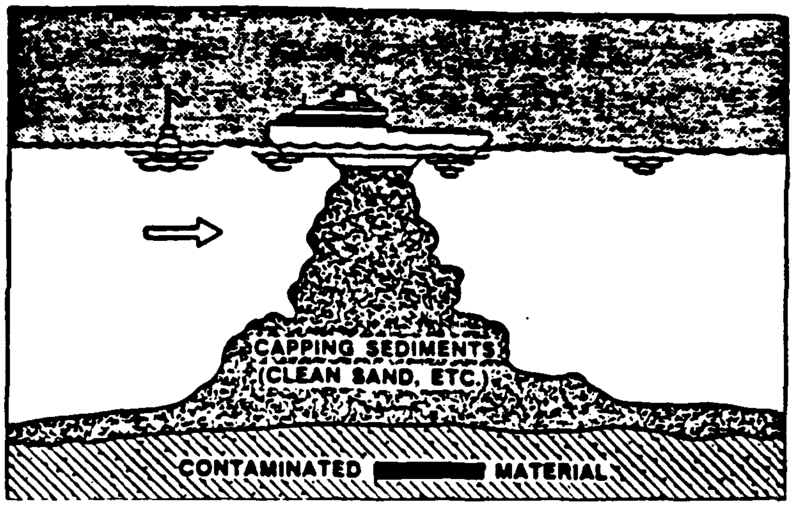
Preparation of the disposal site through excavation of an underwater cell into which the contaminated materials are placed and covered is an effective means of controlling subaquatic placement. Material from this excavation should be relatively clear and can be disposed of through unconfined means or may be stockpiled for subsequent covering of the contaminated sediments in the cell. Predisposal excavation can create a superior disposal site and provide clean material for covering the contaminated sediments. If the surrounding sediments are unsuitable then cleaner sediments from elsewhere or other earthen material must be available for placement over the polluted sediments in the cell. Since the vast majority of the Onondaga Lake bottom is covered with mercury contaminated sediments,there does not appear to be a readily available source of clean cover material in the lake. Additionally, the excavation of a cell in Onondaga Lake would require the dredging and temporary storage of mercury contaminated sediment from the upper portions of the lake bottom sediments.

In order to avoid having to store contaminated sediment and avoid the adverse impacts of dredging, capping of polluted material in place was considered. Figure 59 shows schematics of two types of capping. It is believed that placing the capping material using a submerged diffuser would result in less resuspension of contaminated sediments than bottom dumping of the capping material. The submerged diffuser would also offer greater control over placement of the capping material. Diffuser placement would likely provide a more uniform cover than placement by mechanical means, i.e., enclosed bucket.

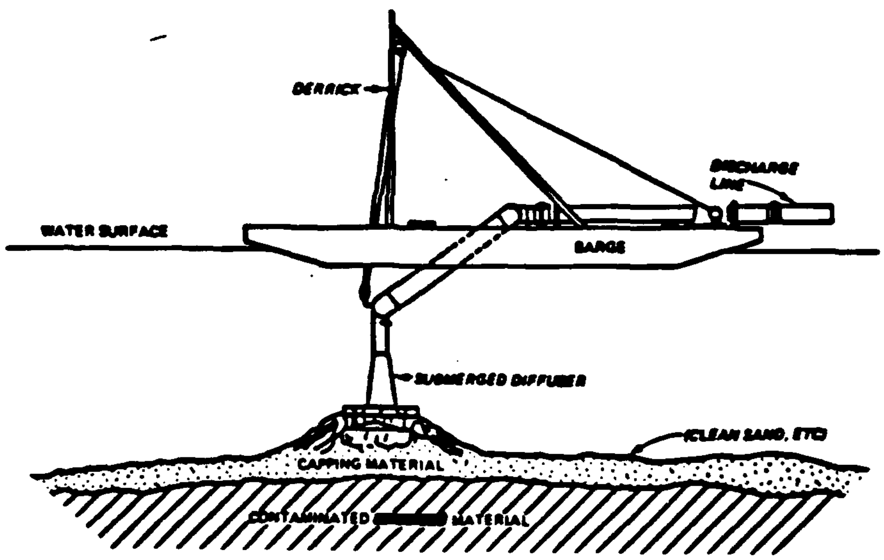
One of the design decisions in a capping project is the nature and thickness of the capping material placed over the contaminated dredged material. The capping material provides the isolation necessary to control the movement of contaminants out of the dredged material and into the overlying water column and prevents direct contact between aquatic biota and the contaminated sediment. Capping also stabilizes the dredged material and protects it from transport or dispersion away from the site. Material used in the capping layer must have a grain size and thickness that provides an adequate seal, yet the material must not be easily suspended and transported by the shear stress at the site.

The sediments which are to be capped should be relatively dense and consolidated. The contaminated materials need to be sufficiently consolidated to support the weight of the capping material. If the materials that are to serve as a cap are denser than the materials to be covered, the capping material is likely to settle through the contaminated sediments, leaving the sediments uncovered. Some modifications may be required to decrease the density of the cap material, or otherwise prevent the capping material from settling into the underlying contaminated sediments.

The cap must provide a physical barrier to isolate the contaminated sediments from contact with the biota in the aquatic environment. Test results indicate that capping material can be effective in isolating contaminated sediment from the overlying water column (Sturgis, Gunnision, 1988). In order to be effective, the cap must be of sufficient thickness to prevent both chemical diffusion and mechanical breaching of the cover. Mechanical breaching can be caused by wave scour and the burrowing of aquatic



Schematic of typical level-bottom capping operation



Schematic showing use of a submerged diffuser for placement

From: Department of the Army, 1987

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SCHEMATIC OF CAPPING OPERATIONS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 59

organisms. Minimum cap thickness needed to prevent physical disturbance to buried contaminated sediments should be a function of the maximum burrowing depth by benthic organisms which are found in the region and erosive forces. Bioturbation by burrowing aquatic organisms is important to the mobility of contaminants. In addition to the possible breaching of a thin cap that may result when organisms disturb the surface sediment, direct exposure of burrowing organisms to the contaminated sediment is a problem. The thickness needed to prevent breaching of cap integrity through bioturbation can be obtained indirectly. Benthic biota of freshwater areas has been fairly well examined, and the depth to which benthic organisms burrow should be available. Normally, the depth which the deepest burrowing organism in the region reaches is used as a safety margin to prevent cap breaching through bioturbation. The erosive forces are a function of wave height and water depth and the currents generated.

The minimum cap thickness needed to achieve total isolation of the contaminated sediments is equal to the sum of the cap thicknesses needed to achieve both physical and chemical isolation. Laboratory and field verification studies have demonstrated that capping of contaminated sediments can be effective in short and long timeframes for preventing the movement of contaminants into the water column. Close short-term monitoring is required to assure that the capping completely covers the contaminated sediments to the minimum thickness required. Long-term monitoring is required to assure that the capping material remains in place. Monitoring is also needed to assure that contaminated sediments have been effectively isolated from the water column.

Confined aquatic disposal (CAD) in naturally deep portions of the lake may be a more feasible alternative than capping in place. This alternative could be investigated in future studies if capping appears to be a reasonable alternative.

5.3.4.1 Estimated Cost

Several reconnaissance level cost estimates were made for capping of contaminated sediments in Onondaga Lake. Figure 41 shows the area, 2,610 acres, that would require capping in order to isolate sediments containing mercury concentrations greater than or equal to 1 ppm. Figures 42 and 43 show the areas requiring capping for mercury concentrations greater than or equal to 5 ppm (2,140 acres) and 10 ppm (1,880 acres), respectively. Four separate estimates were made for capping each of these areas with 0.5 foot, 1.0 foot, 2.0 feet, and 3.0 feet of sand capping material. However, for contaminated sediments in less than 15 feet of water, a three layer cap consisting of 3 feet of sand covered by 2 feet of gravel and 2 feet of armor stone (6 to 18 inch in size) would be required to protect against erosional forces. In water depths ranging from 15 to 25 feet contaminated sediments would be covered with a two layer cap consisting of 3 feet of sand covered by 2 feet of gravel to protect against erosional forces. In water depths exceeding 25 feet, the contaminated sediments would be covered only with the sand capping material. For estimating purposes, it was assumed that 10 percent of the areas to be capped would be covered with the three layer cap while 15 percent of the areas to be capped would be covered with the two layer system. The remaining 75 percent of the areas will be covered only with 0.5 to 3.0 feet of the sand

capping material. It is anticipated that sand borrow will be available within 10 miles while the gravel and armor stone will be obtained from quarries in the area.

A summary of the estimates for the various capping options is shown in Table 21. Detailed estimates for the various capping options are shown in Tables 22-33. These preliminary cost estimates are based on June 1[illegible] price levels and include planning, engineering and design, and construction costs.

Table 21 Summary of Estimates for Capping Measures

A. Sediments With 1 ppm Hg or Greater - Cover 75 percent of Contaminated Sediments With:

1. 0.5 foot of Sand; plus Shallow Water Cap	$ 198,000,000
2. 1.0 foot of Sand; plus Shallow Water Cap	$ 226,000,000
3. 2.0 feet of Sand; plus Shallow Water Cap	$ 284,000,000
4. 3.0 feet of Sand; plus Shallow Water Cap	$ 341,000,000

B. Sediments With 5 ppm Hg or Greater - Cover 75 percent of Contaminated Sediments With:

1. 0.5 foot of Sand; plus Shallow Water Cap	$ 162,000,000
2. 1.0 foot of Sand; plus Shallow Water Cap	$ 186,000,000
3. 2.0 feet of Sand; plus Shallow Water Cap	$ 233,000,000
4. 3.0 feet of Sand; plus Shallow Water Cap	$ 280,000,000

C. Sediments With 10 ppm Hg or Greater - Cover 75 percent of Contaminated Sediments With:

1. 0.5 foot of Sand; plus Shallow Water Cap	$ 143,000,000
2. 1.0 foot of Sand; plus Shallow Water Cap	$ 163,000,000
3. 2.0 feet of Sand; plus Shallow Water Cap	$ 205,000,000
4. 3.0 feet of Sand; plus Shallow Water Cap	$ 246,000,000

5.4 Waste Beds

Allied Signal prepared a report entitled "Hydrogeologic Assessment of the Allied Waste Beds in the Syracuse Area" to comply with a Consent Order with the New York State Department of Environmental Conservation (NYSDEC) (Blasland and Bouck Eng., 1989). Several remedial alternatives were proposed that could reduce leachate from the waste beds from entering the environment. A Waste Bed Feasibility Study has been prepared by Allied. The report as of November 1990, is in draft format and is ready for technical evaluation.

In general, the remedial measures that are potentially applicable to the waste beds and ground water are summarized below:

Potential Alternatives Which Address Waste Deposits

- no action
- grading, cover, and vegetation
- grading, low permeability cap and vegetation
- grading, low permeability cap, ground water cutoff wall, and vegetation
- sludge incorporation and vegetation
- off-site disposal

Table 22 Cost Estimate for Capping Sediments Contaminated with 1 PPM Hg (0.5 Foot of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 0.5 FOOT OF SAND						
SAND CAP	2,368,000	TON	8.00	18,944,000	5,683,000	24,627,000
TOTAL CONSTRUCTION COST				18,944,000	5,683,000	24,627,000
PLANNING, ENGINEERING & DESIGN				2,227,000	-	2,227,000
CONSTRUCTION MANAGEMENT				1,830,000	-	1,830,000
TOTAL				$23,001,000	$ 5,683,000	$28,684,000
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,842,600	TON	8.00	22,740,000	6,822,000	29,562,000
GRAVEL CAP	1,769,000	TON	15.00	26,535,000	7,960,000	34,495,000
TOTAL CONSTRUCTION COST				49,275,000	14,782,000	64,057,000
PLANNING, ENGINEERING & DESIGN				5,795,000	-	5,795,000
CONSTRUCTION MANAGEMENT				4,819,000	-	4,819,000
SUB TOTAL				$59,889,000	$14,782,000	$74,671,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,894,700	TON	8.00	15,158,000	4,547,400	19,705,000
GRAVEL CAP	1,178,500	TON	15.00	17,678,000	5,303,000	22,981,000
ARMOR STONE CAP	1,178,500	TON	25.00	29,463,00	8,839,000	38,302,000
TOTAL CONSTRUCTION COST				62,299,000	18,689,400	80,988,400
PLANNING, ENGINEERING & DESIGN				7,320,000	-	7,320,000
CONSTRUCTION MANAGEMENT				6,100,000	-	6,100,000
SUB TOTAL				$75,719,000	$18,689,400	$94,408,400
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$158,609,000$	39,154,400	$197,763,400

Table 23 Cost Estimate for Capping Sediments Contaminated with 1 PPM Hg (1.0 Foot of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 1.0 FOOT OF SAND						
SAND CAP	4,736,000	TON	8.00	37,888,000	11,366,000	49,254,000
TOTAL CONSTRUCTION COST				37,888,000	11,366,000	49,254,000
PLANNING, ENGINEERING & DESIGN				4,453,000	-	4,453,000
CONSTRUCTION MANAGEMENT				3,660,000	-	3,660,000
SUB TOTAL				$46,001,000	$11,366,000	$57,367,000
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,842,600	TON	8.00	22,740,000	6,822,000	29,562,000
GRAVEL CAP	1,769,000	TON	15.00	26,535,000	7,960,000	34,495,000
TOTAL CONSTRUCTION COST				49,275,000	14,782,000	64,057,000
PLANNING, ENGINEERING & DESIGN				5,795,000	-	5,795,000
CONSTRUCTION MANAGEMENT				4,819,000	-	4,819,000
SUB TOTAL				$59,889,000	$14,782,000	$74,671,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,894,700	TON	8.00	15,158,000	4,547,400	19,705,000
GRAVEL CAP	1,178,500	TON	15.00	17,678,000	5,303,000	22,981,000
ARMOR STONE CAP	1,178,500	TON	25.00	29,463,000	8,839,000	38,302,000
TOTAL CONSTRUCTION COST				62,299,000	18,689,400	80,988,400
PLANNING, ENGINEERING & DESIGN				7,320,000	-	7,320,000
CONSTRUCTION MANAGEMENT				6,100,000	-	6,100,000
SUB TOTAL				$75,719,000	$18,689,400	$94,408,400
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$181,609,000	$44,837,400	$226,446,400

Table 24 Cost Estimate for Capping Sediments Contaminated with 1 PPM Hg (2.0 Feet of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 2.0 FOOT OF SAND						
SAND CAP	9,472,000	TON	8.00	75,776,000	22,733,000	98,509,000
TOTAL CONSTRUCTION COST				75,766,000	22,733,000	98,509,000
PLANNING, ENGINEERING & DESIGN				8,900,000	-	8,900,000
CONSTRUCTION MANAGEMENT				7,380,000	-	7,380,000
SUB TOTAL				$92,056,000	$22,733,000	$114,789,000
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,842,600	TON	8.00	22,740,000	6,822,000	29,562,000
GRAVEL CAP	1,769,000	TON	15.00	26,535,000	7,960,000	34,495,000
TOTAL CONSTRUCTION COST				49,275,000	14,782,000	64,057,000
PLANNING, ENGINEERING & DESIGN				5,795,000	-	5,795,000
CONSTRUCTION MANAGEMENT				4,819,000	-	4,819,000
SUB TOTAL				$59,889,000	$14,782,000	$74,671,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,894,700	TON	8.00	15,158,000	4,547,400	19,705,000
GRAVEL CAP	1,178,500	TON	15.00	17,678,000	5,303,000	22,981,000
ARMOR STONE CAP	1,178,500	TON	25.00	29,463,000	8,839,000	38,302,000
TOTAL CONSTRUCTION COST				62,299,000	18,689,400	80,988,400
PLANNING, ENGINEERING & DESIGN				7,320,000	-	7,320,000
CONSTRUCTION MANAGEMENT				6,100,000	-	6,100,000
SUB TOTAL				$75,719,000	$18,689,400	$94,408,400
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$227,664,000	$56,204,400	$283,868,400

Table 25 Cost Estimate for Capping Sediments Contaminated with 1 PPM Hg (3.0 Feet of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 3.0 FEET OF SAND						
SAND CAP	14,208,000	TON	8.00	113,664,000	34,099,000	147,763,000
TOTAL CONSTRUCTION COST				113,644,000	34,099,000	147,763,000
PLANNING, ENGINEERING & DESIGN				13,360,000	-	13,360,000
CONSTRUCTION MANAGEMENT				10,980,000	-	10,980,000
SUB TOTAL				$138,004,000	$34,099,000	$172,103,000
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,842,600	TON	8.00	22,740,000	6,822,000	29,562,000
GRAVEL CAP	1,769,000	TON	15.00	26,535,000	7,960,000	34,495,000
TOTAL CONSTRUCTION COST				49,275,000	14,782,000	64,057,000
PLANNING, ENGINEERING & DESIGN				5,795,000	-	5,795,000
CONSTRUCTION MANAGEMENT				4,819,000	-	4,819,000
SUB TOTAL				$59,889,000	$14,782,000	$74,671,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,894,700	TON	8.00	15,158,000	4,547,400	19,705,000
GRAVEL CAP	1,178,500	TON	15.00	17,678,000	5,303,000	22,981,000
ARMOR STONE CAP	1,178,500	TON	25.00	29,463,000	8,839,000	38,302,000
TOTAL CONSTRUCTION COST				62,299,000	18,689,400	80,988,400
PLANNING, ENGINEERING & DESIGN				7,320,000	-	7,320,000
CONSTRUCTION MANAGEMENT				6,100,000	-	6,100,000
SUB TOTAL				$75,719,000	$18,689,400	$94,408,400
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$273,612,000	$67,570,400	$341,182,400

Table 26 Cost Estimate for Capping Sediments Contaminated with 5 PPM Hg (0.5 Foot of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 0.5 FOOT OF SAND						
SAND CAP	1,941,000	TON	8.00	15,528,000	4,658,400	20,186,400
TOTAL CONSTRUCTION COST				15,528,000	4,658,400	20,186,400
PLANNING, ENGINEERING & DESIGN				1,825,000	-	1,825,000
CONSTRUCTION MANAGEMENT				1,500,000	-	1,500,000
SUB TOTAL				$18,853,000	$ 4,658,400	$23,511,400
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,330,000	TON	8.00	18,640,000	5,592,000	24,232,000
GRAVEL CAP	1,450,000	TON	15.00	21,750,000	6,525,000	28,275,000
TOTAL CONSTRUCTION COST				40,390,000	12,117,000	52,507,000
PLANNING, ENGINEERING & DESIGN				4,750,000	-	4,750,000
CONSTRUCTION MANAGEMENT				3,950,000	-	3,950,000
SUB TOTAL				$49,090,000	$12,117,000	$61,207,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,553,000	TON	8.00	12,424,000	3,727,200	16,151,200
GRAVEL CAP	966,000	TON	15.00	14,490,000	4,347,000	18,837,000
ARMOR STONE CAP	966,000	TON	25.00	24,150,000	7,245,000	31,395,000
TOTAL CONSTRUCTION COST				51,064,000	15,319,200	66,383,200
PLANNING, ENGINEERING & DESIGN				6,000,000	-	6,000,000
CONSTRUCTION MANAGEMENT				5,000,000	-	5,000,000
SUB TOTAL				$62,064,000	$15,319,200	$77,383,200
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$130,007,000	$32,094,600	$162,101,600

Table 27 Cost Estimate for Capping Sediments Contaminated with 5 PPM Hg (1.0 Foot of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 1.0 FOOT OF SAND						
SAND CAP	3,882,000	TON	8.00	31,056,000	9,316,800	40,372,800
TOTAL CONSTRUCTION COST				31,056,000	9,316,800	40,372,800
PLANNING, ENGINEERING & DESIGN				3,650,000	-	3,650,000
CONSTRUCTION MANAGEMENT				3,000,000	-	3,000,000
SUB TOTAL				$37,706,000	$ 9,316,800	$47,022,800
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,330,000	TON	8.00	18,640,000	5,592,000	24,232,000
GRAVEL CAP	1,450,000	TON	15.00	21,750,000	6,525,000	28,275,000
TOTAL CONSTRUCTION COST				40,390,000	12,117,000	52,507,000
PLANNING, ENGINEERING & DESIGN				4,750,000	-	4,750,000
CONSTRUCTION MANAGEMENT				3,950,000	-	3,950,000
SUB TOTAL				$49,090,000	$12,117,000	$61,207,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,553,000	TON	8.00	12,424,000	3,727,200	16,151,200
GRAVEL CAP	966,000	TON	15.00	14,490,000	4,347,000	18,837,000
ARMOR STONE CAP	966,000	TON	25.00	24,150,000	7,245,000	31,395,000
TOTAL CONSTRUCTION COST				51,064,000	15,319,200	66,383,200
PLANNING, ENGINEERING & DESIGN				6,000,000	-	6,000,000
CONSTRUCTION MANAGEMENT				5,000,000	-	5,000,000
SUB TOTAL				$62,064,000	$15,319,200	$77,383,200
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$148,860,000	$36,753,000	$185,613,000

Table 28 Cost Estimate for Capping Sediments Contaminated with 5 PPM Hg
(2.0 Feet of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 2.0 FOOT OF SAND						
SAND CAP	7,764,000	TON	8.00	62,112,000	18,633,600	80,745,600
TOTAL CONSTRUCTION COST				62,112,000	18,633,600	80,745,600
PLANNING, ENGINEERING & DESIGN				7,300,000	-	7,300,000
CONSTRUCTION MANAGEMENT				6,050,000	-	6,050,000
SUB TOTAL				$75,462,000	$18,633,600	$94,095,600
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,330,000	TON	8.00	18,640,000	5,592,000	24,232,000
GRAVEL CAP	1,450,000	TON	15.00	21,750,000	6,525,000	28,275,000
TOTAL CONSTRUCTION COST				40,390,000	12,117,000	52,507,000
PLANNING, ENGINEERING & DESIGN				4,750,000	-	4,750,000
CONSTRUCTION MANAGEMENT				3,950,000	-	3,950,000
SUB TOTAL				$49,090,000	$12,117,000	$61,207,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,553,000	TON	8.00	12,424,000	3,727,200	16,151,200
GRAVEL CAP	966,000	TON	15.00	14,490,000	4,347,000	18,837,000
ARMOR STONE CAP	966,000	TON	25.00	24,150,000	7,245.000	31,395,000
TOTAL CONSTRUCTION COST				51,064,000	15,319,200	66,383,200
PLANNING, ENGINEERING & DESIGN				6,000,000	-	6,000,000
CONSTRUCTION MANAGEMENT				5,000,000	-	5,000,000
SUB TOTAL				$62,064,000	$15,319,200	$77,383,200
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$186,616,000	$46,069,800	$232,685,800

Table 29 Cost Estimate for Capping Sediments Contaminated with 5 PPM Hg (3.0 Feet of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 3.0 FOOT OF SAND						
SAND CAP	11,646,000	TON	8.00	93,168,000	27,950,400	121,118,400
TOTAL CONSTRUCTION COST				93,168,000	27,950,400	121,118,400
PLANNING, ENGINEERING & DESIGN				10,950,000	-	10,950,000
CONSTRUCTION MANAGEMENT				9,000,000	-	9,000,000
SUB TOTAL				$113,118,000	$27,950,400	$141,068,400
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,330,000	TON	8.00	18,640,000	5,592,000	24,232,000
GRAVEL CAP	1,450,000	TON	15.00	21,750,000	6,525,000	28,275,000
TOTAL CONSTRUCTION COST				40,390,000	12,117,000	52,507,000
PLANNING, ENGINEERING & DESIGN				4,750,000	-	4,750,000
CONSTRUCTION MANAGEMENT				3,950,000	-	3,950,000
SUB TOTAL				$49,090,000	$12,117,000	$61,207,000
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,553,000	TON	8.00	12,424,000	3,727,200	16,151,200
GRAVEL CAP	966,000	TON	15.00	14,490,000	4,347,000	18,837,000
ARMOR STONE CAP	966,000	TON	25.00	24,150,000	7,245,000	31,395,000
TOTAL CONSTRUCTION COST				51,064,000	15,319,200	66,383,200
PLANNING, ENGINEERING & DESIGN				6,000,000	-	6,000,000
CONSTRUCTION MANAGEMENT				5,000,000	-	5,000,000
SUB TOTAL				$62,064,000	$15,319,200	$77,383,200
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$224,272,000	$55,386,600	$279,658,600

Table 30 Cost Estimate for Capping Sediments Contaminated with 10 PPM Hg
(0.5 Foot of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 0.5 FOOT OF SAND						
SAND CAP	1,706,000	TON	8.00	13,648,000	4,094,400	17,742,400
TOTAL CONSTRUCTION COST				13,648,000	4,094,400	17,742,400
PLANNING, ENGINEERING & DESIGN				1,600,000	-	1,600,000
CONSTRUCTION MANAGEMENT				1,320,000	-	1,320,000
SUB TOTAL				$16,568,000	$ 4,094,400	$20,662,400
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,048,000	TON	8.00	16,384,000	4,915,200	21,299,200
GRAVEL CAP	1,275,000	TON	15.00	19,125,000	5,737,500	24,862,500
TOTAL CONSTRUCTION COST				35,509,000	10,652,700	46,161,700
PLANNING, ENGINEERING & DESIGN				4,175,000	-	4,175,000
CONSTRUCTION MANAGEMENT				3,470,000	-	3,470,000
SUB TOTAL				$43,154,000	$10,652,700	$53,806,700
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,365,000	TON	8.00	10,920,000	3,276,000	14,196,000
GRAVEL CAP	849,000	TON	15.00	12,735,000	3,820,500	16,555,500
ARMOR STONE CAP	849,000	TON	25.00	21,228,000	6,368,400	27,596,400
TOTAL CONSTRUCTION COST				44,883,000	13,464,900	58,347,900
PLANNING, ENGINEERING & DESIGN				5,275,000	-	5,275,000
CONSTRUCTION MANAGEMENT				4,400,000	-	4,400,000
SUB TOTAL				$54,558,000	$13,464,900	$68,022,900
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$114,280,000	$28,212,000	$142,492,000

Table 31 Cost Estimate for Capping Sediments Contaminated with 10 PPM Hg
(1.0 Foot of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 1.0 FOOT OF SAND						
SAND CAP	3,412,000	TON	8.00	27,296,000	8,188,800	35,484,800
TOTAL CONSTRUCTION COST				27,296,000	8,188,800	35,484,800
PLANNING, ENGINEERING & DESIGN				3,210,000	-	3,210,000
CONSTRUCTION MANAGEMENT				2,640,000	-	2,640,000
SUB TOTAL				$33,146,000	$ 8,188,800	$41,334,800
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,048,000	TON	8.00	16,384,000	4,915,200	21,299,200
GRAVEL CAP	1,275,000	TON	15.00	19,125,000	5,737,500	24,862,500
TOTAL CONSTRUCTION COST				35,509,000	10,652,700	46,161,700
PLANNING, ENGINEERING & DESIGN				4,175,000	-	4,175,000
CONSTRUCTION MANAGEMENT				3,470,000	-	3,470,000
SUB TOTAL				$43,154,000	$10,652,700	$53,806,700
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,365,000	TON	8.00	10,920,000	3,276,000	14,196,000
GRAVEL CAP	849,000	TON	15.00	12,735,000	3,820,500	16,555,500
ARMOR STONE CAP	849,000	TON	25.00	21,228,000	6,368,400	27,596,400
TOTAL CONSTRUCTION COST				44,883,000	13,464,900	58,347,900
PLANNING, ENGINEERING & DESIGN				5,275,000	-	5,275,000
CONSTRUCTION MANAGEMENT				4,400,000	-	4,400,000
SUB TOTAL				$54,558,000	$13,464,900	$68,022,900
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$130,858,000	$32,306,400	$163,164,400

Table 32 Cost Estimate for Capping Sediments Contaminated with 10 PPM Hg
(2.0 Feet of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 2.0 FEET OF SAND						
SAND CAP	6,825,000	TON	8.00	54,600,000	16,380,000	70,980,000
TOTAL CONSTRUCTION COST				54,600,000	16,380,000	70,980,000
PLANNING, ENGINEERING & DESIGN				6,420,000	-	6,420,000
CONSTRUCTION MANAGEMENT				5,320,000	-	5,320,000
SUB TOTAL				$66,340,000	$16,380,000	$82,720,000
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,048,000	TON	8.00	16,384,000	4,915,200	21,299,200
GRAVEL CAP	1,275,000	TON	15.00	19,125,000	5,737,500	24,862,500
TOTAL CONSTRUCTION COST				35,509,000	10,652,700	46,161,700
PLANNING, ENGINEERING & DESIGN				4,175,000	-	4,175,000
CONSTRUCTION MANAGEMENT				3,470,000	-	3,470,000
SUB TOTAL				$43,154,000	$10,652,700	$53,806,700
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,365,000	TON	8.00	10,920,000	3,276,000	14,196,000
GRAVEL CAP	849,000	TON	15.00	12,735,000	3,820,500	16,555,500
ARMOR STONE CAP	849,000	TON	25.00	21,228,000	6,368,400	27,596,400
TOTAL CONSTRUCTION COST				44,883,000	13,464,900	58,347,900
PLANNING, ENGINEERING & DESIGN				5,275,000	-	5,275,000
CONSTRUCTION MANAGEMENT				4,400,000	-	4,400,000
SUB TOTAL				$54,558,000	$13,464,900	$68,022,900
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$164,052,000	$40,497,600	$204,549,600

Table 33 Cost Estimate for Capping Sediments Contaminated with 10 PPM Hg (3.0 Feet of Sand)

DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT	CONTINGENCY	TOTAL
COVER 75% OF LAKE WITH 3.0 FEET OF SAND						
SAND CAP	10,237,000	TON	8.00	81,896,000	24,568,800	106,464,800
TOTAL CONSTRUCTION COST				81,896,000	24,568,800	106,464,800
PLANNING, ENGINEERING & DESIGN				9,625,000	-	9,625,000
CONSTRUCTION MANAGEMENT				7,910,000	-	7,910,000
SUB TOTAL				$99,431,000	$24,568,800	$123,999,800
COVER 15% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL						
SAND CAP	2,048,000	TON	8.00	16,384,000	4,915,200	21,299,200
GRAVEL CAP	1,275,000	TON	15.00	19,125,000	5,737,500	24,862,500
TOTAL CONSTRUCTION COST				35,509,000	10,652,700	46,161,700
PLANNING, ENGINEERING & DESIGN				4,175,000	-	4,175,000
CONSTRUCTION MANAGEMENT				3,470,000	-	3,470,000
SUB TOTAL				$43,154,000	$10,652,700	$53,806,700
COVER 10% OF LAKE WITH 3.0 FOOT OF SAND AND 2.0 FOOT OF GRAVEL AND 2.0 FOOT OF ARMOR STONE						
SAND CAP	1,365,000	TON	8.00	10,920,000	3,276,000	14,196,000
GRAVEL CAP	849,000	TON	15.00	12,735,000	3,820,500	16,555,500
ARMOR STONE CAP	849,000	TON	25.00	21,228,000	6,368,400	27,596,400
TOTAL CONSTRUCTION COST				44,883,000	13,464,900	58,347,900
PLANNING, ENGINEERING & DESIGN				5,275,000	-	5,275,000
CONSTRUCTION MANAGEMENT				4,400,000	-	4,400,000
SUB TOTAL				$54,558,000	$13,464,900	$68,022,900
REAL ESTATE:						
LANDS, EASEMENTS & RIGHTS OF WAY				-	-	-
ADMINISTRATION				-	-	-
TOTAL				$197,143,000	$48,686,400	$245,829,400

The preliminary costs of these measures range from $222,000 to $162,400,000, based on various combinations. The minimal cost estimate is based on a "no action" approach. The maximum cost is based on a combination of the most elaborate system.

Potential Alternatives Which Address Ground Water and Seeps

- no action
- control of waste bed seeps
- ground-water withdrawal and discharge
- ground-water withdrawal and treatment, and
- Nine Mile Creek Rechannelization

Preliminary costs for these measures range from $31,700,000 to $85,800,000.

The Allied Feasibility Study will screen the potential remedial alternatives on the basis of technical feasibility only.

5.5 Mud Boils

The mud boils are interpreted to be upwelling springs. Artesian waters apparently migrate vertically from depth and suspend and transport large quantities of sediment from the glacial overburden. Individual mud boils appear as turbid spring upwellings, ranging from 1 inch to 15 feet in diameter. In some instances, a high sand and silt fraction of the rising waters is deposited around the vertically piped rising spring water in such a manner as to give the appearance of miniature volcanoes, with small central craters. The mud boils periodically shift location and degree of activity.

Anecdotal evidence obtained by the State of New York suggests that a few mud boils were present immediately south of Otisco Road, just west of Onondaga Creek before 1913. Although overgrown today, this area can still be observed. Anecdotal reports confirm the presence of a few very small mud boils at this location in the late 1930s and early 1940s. These mud boils were small and apparently did not adversely effect the water quality of Onondaga Creek.

Preliminary review of historic aerial photography reveals that the largest mud boil field, approximately 1,800 feet south of Otisco Road was not present as of April 1967. By April 1972, the largest mud boil field measured approximately 200 feet long by 80 feet wide. Land photographs and reported field observations by USGS and Sun Pipeline personnel in the mid-1970's indicate that the area may have been smaller. By March 1981, this area had expanded to approximately 525 feet long by 240 feet wide. Field measurements made in 1989 documented the maximum length and width of the subsiding area here as 625 by 575 feet. By August 1987, a smaller subsidence area in Onondaga Creek had formed several hundred feet to the west and in alignment with the large mud boil field. This second area continues to grow at an apparently rapid rate as does the main area. Mud boil field expansion is occurring both from north and south and east-west.

Two additional mud boils have been located and sampled for chemical analysis approximately 2,400 and 6,100 feet south of the largest mud boil

field. The southern-most of these two mud boils, situated on the Haynes farm, is some 2,900 feet northeast of the northern-most Allied East Field brine well. Mud boils have appeared on the Snavlin and Haynes farms sporadically since the 1950s. The Haynes mud boil is located on a gravel stream terrace 6 feet higher in elevation than the nearby Onondaga Creek.

The discharge and sediment input to Onondaga Creek from the mud boil areas has apparently increased through time as more and more boils have formed. Effusion from the first mud boils was apparently minimal. According to anecdotal information provided by residents of the Valley, mud boil effusions caused noticeable intermittent turbidity in Onondaga Creek by the mid-to-late 1960s. Between approximately 1960 and 1972, numerous mud boils appeared between the original few boils next to Otisco Road and the large mud boil field known today. The magnitude of the increasing discharge is exemplified in the rapid growth of the current mud boil field south of Otisco Road.

The mud boil effluent generally contains approximately 25 to 75 percent sediment, much of which settles out with distance from the mud boils. What does not settle out in Onondaga Creek eventually reaches Onondaga Lake. (State of New York, September 1990)

5.5.1 Description of Plan

The plan which addresses the mud boil contribution of sediment to Onondaga Creek consists of diversion of the tributary which runs through the mud boil field and excavation of a settling basin to trap the sediment emanating from the residual flow. This is shown in Figure 60.

The diversion will consist of a new channel cut through a field to join an existing tributary. The excavated channel will have a 5 foot bottom width, 1V on 2H sideslopes and be approximately 10 feet in depth as shown in Figure 61. This section will be approximately 1,200 feet long. The existing tributary which it will join must be enlarged to accommodate the additional flow as shown in Figure 62. This cut will be approximately 800 feet long.

The settling basin will be located just upstream of the mud boil field tributary's confluence with Onondaga Creek. The design was based on a mudboil flowrate of 3 CFS, a settling velocity of 0.00056 feet per second, a concentration of 3.8 g/l, and a specific gravity of 2.45. Efficiency was based on a relation given in the United States Bureau of Reclamation Boulder Canyon Project Final Report. It will be 500 feet long by 40 feet wide and have a depth of 8 feet as shown in Figures 63 and 64. This configuration will trap approximately 98 percent of the sediment which enters the basin. The accumulated sediment would have to be removed on an annual basis and spoiled at an upland site. The trapped sediment would be approximately 910 tons/month or 440 cubic yards/month.

5.5.2 Cost Estimate

A preliminary cost estimate for the proposed plan is shown in Table 34 below. These are January 1991 price levels. It was assumed that upland disposal within 1,000 feet of the basin was practical. Use of a CDF was not assumed. Beneficial use is probably not feasible due to high sodium and chloride concentrations. In general, the disposal issue requires additional studies.

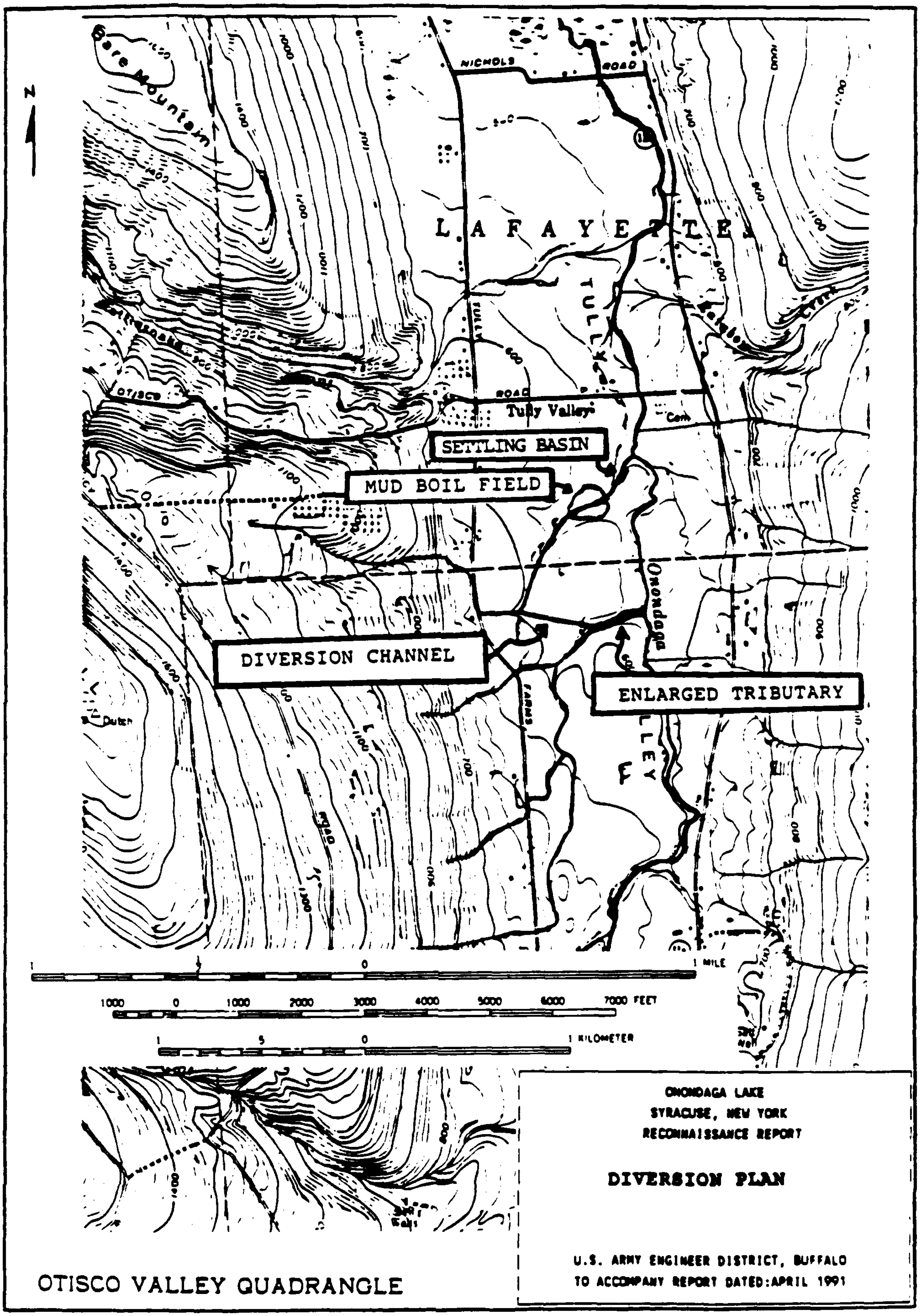

N
NICHOLS ROAD
L A F A Y E T T E
TULLY
ROAD
Tully Valley
SETTLING BASIN
MUD BOIL FIELD
DIVERSION CHANNEL
ENLARGED TRIBUTARY
Onondaga
VALLEY
1 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT
DIVERSION PLAN
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991
OTISCO VALLEY QUADRANGLE

Figure 60

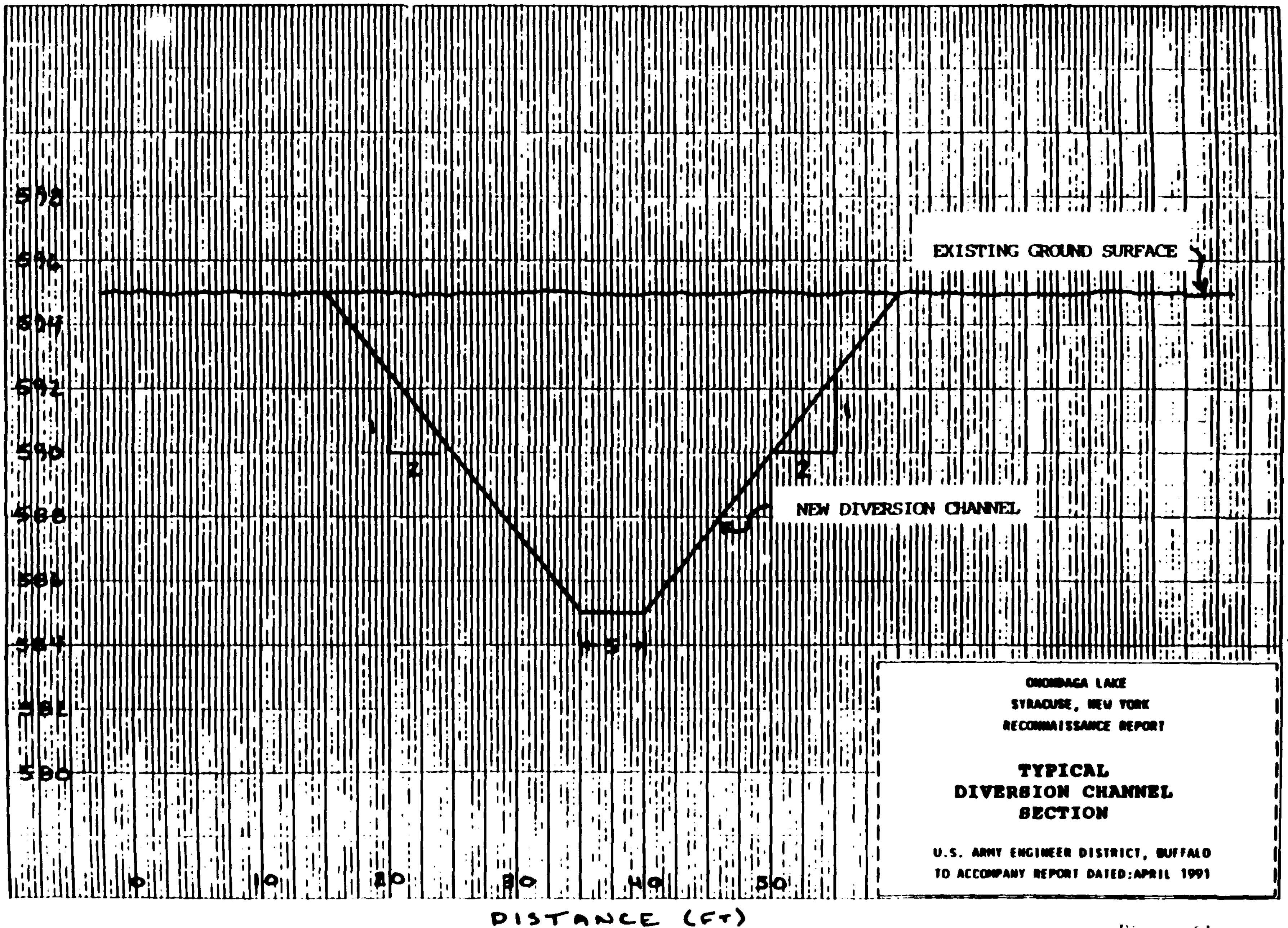

598
596
594
592
590
588
586
584
582
580
ELEVATION (FT)
0
10
20
30
40
50
DISTANCE (FT)
EXISTING GROUND SURFACE
NEW DIVERSION CHANNEL
1
2
5
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT
TYPICAL
DIVERSION CHANNEL
SECTION
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991
46 1240

Figure 61

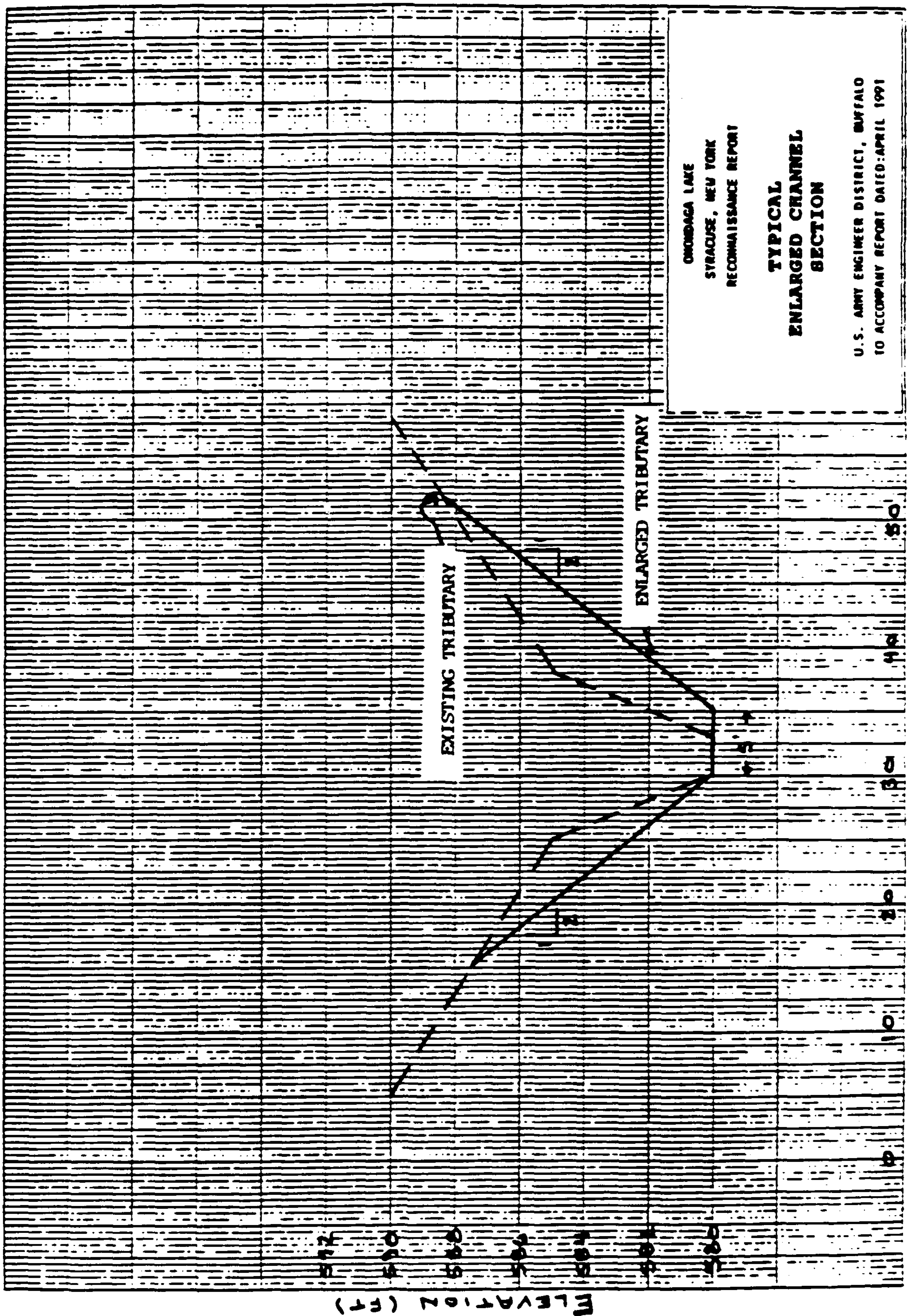


Figure 62

Figure 62

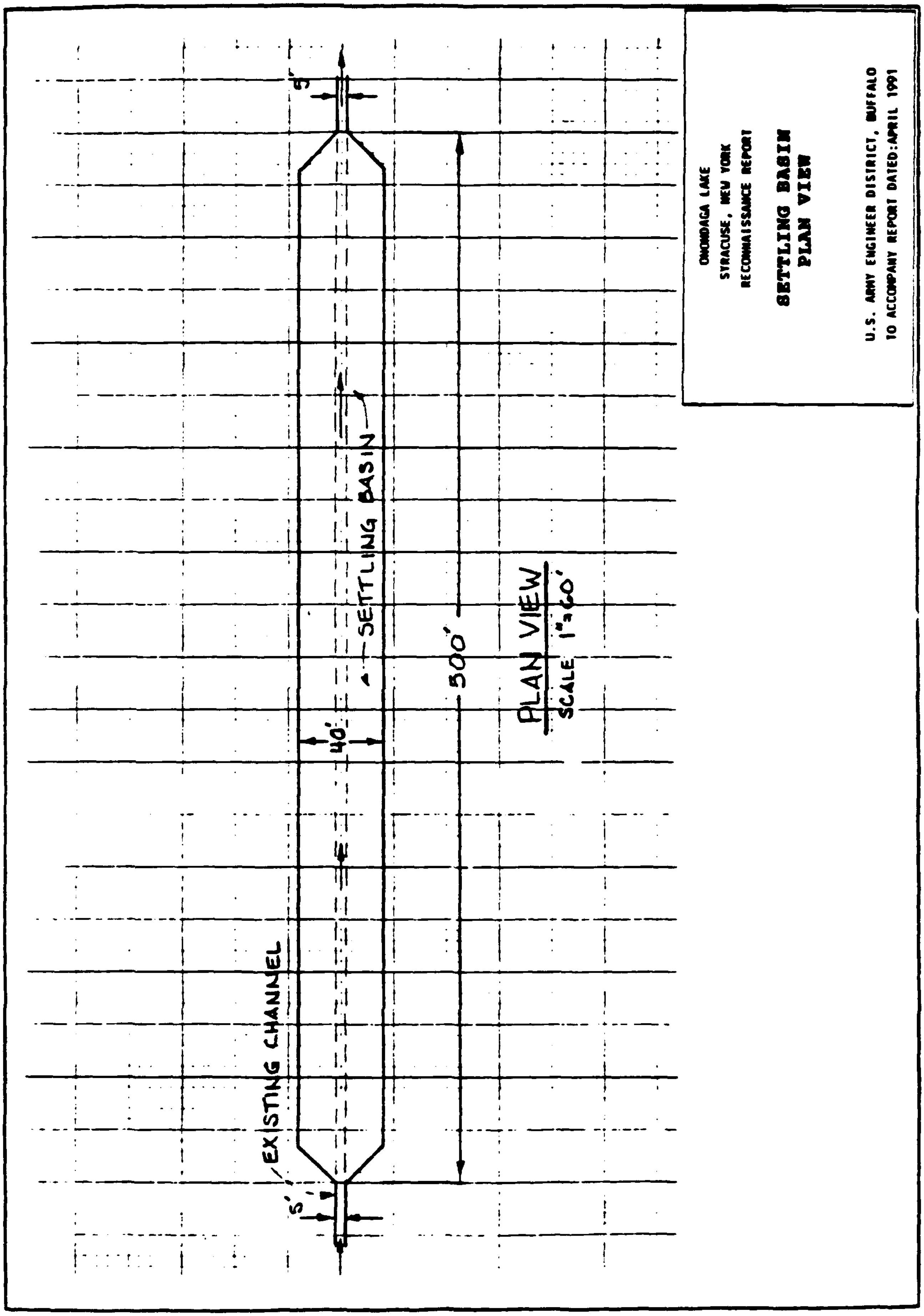


Figure 63

Figure 63

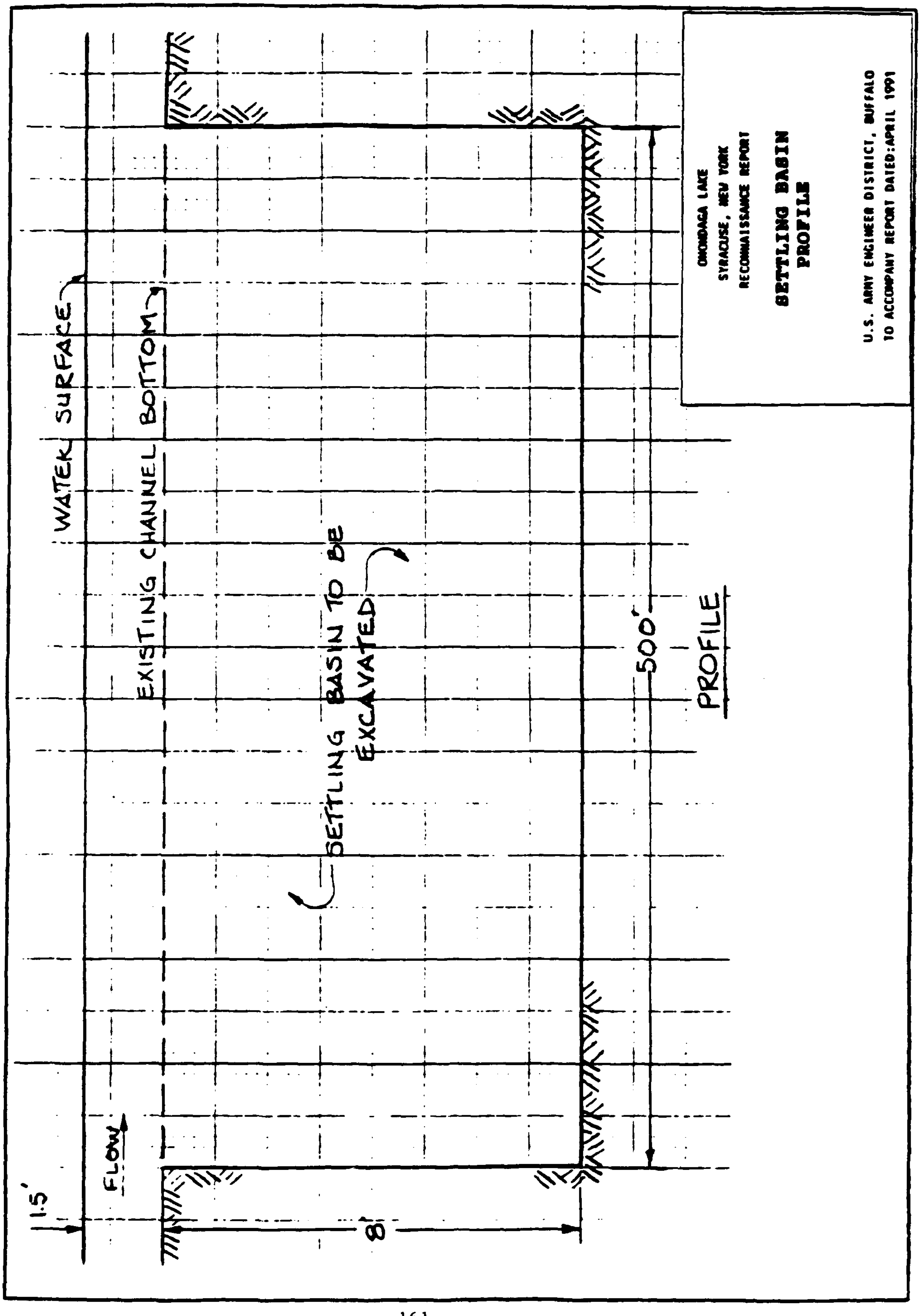


Figure 64

Figure 64

Table 34 Cost Estimate for Mud Boil Sediment Remediation

Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total
Channel Excavation	21,300	CY	10.50	223,650	55,913	279,563
Grass Seeding	9,200	SY	0.50	4,600	1,150	5,750
2 culvert cross-overs	2	EA	5,000	10,000	1,000	11,000
Total Construction Cost				238,250	58,063	296,313
Real Estate						
Lands, Easements, & Rights-of-way (9 acres)				-	-	-
administration				-	-	-
Planning, Engineering & Design @ 12%				27,390	6,848	34,238
Construction Management @ 10%				22,825	5,706	28,531
Total				$278,465	$69,616	$348,081
						SAY $348,000
Annual Sediment Removal	5,300	CY	10.50	55,650	13,913	69,563

5.6 In-lake Treatments

5.6.1 Hypolimnetic Aeration/Oxygenation

Eutrophication of lakes leads to nuisance algae growth, anaerobic hypolimnetic conditions, a general deterioration of water quality, and a possible precluded use of the water by man. Eutrophication is generally conceived as a long-term natural process, but can be greatly accelerated by man. This is certainly the case with Onondaga Lake.

Artificial aeration is often used to reduce certain undesirable conditions associated with eutrophication. Two principal categories of lake aeration are destratification with complete mixing and hypolimnetic aeration. Destratification involves the upwelling of hypolimnetic water to the surface where it is mixed with eplimnetic and thermocline water. When destratification is accomplished, the lake will be isothermal, oxygen will be present at all depths, and other chemical conditions will be more uniform in profile concentrations. Oxygen continues to enter through the lake surface and is available to all the waters of the lake. A properly designed destratification system can improve water quality; however, an inadequate system could cause greater problems (Holland and Tate, 1984, Lorenzen and Fast, 1977, Pastorok, et al., 1982). On the other hand, hypolimnetic aeration consists of the aeration of the hypolimnion without changing the thermal stratification of the lake. Several hypolimnetic aeration systems have been designed and used. Hypolimnetic aeration has certain advantages over destratification including: control on nutrient production and recycling and the production of cold, well-oxygenated water during the warm summer months that can be used as a cold water fishery for trout, salmon, and related cold water fish.

At this point only hypolimnetic aerators or oxygenators will be considered because of the desire to restore the lake to its previous trophic condition of cold well-oxygenated hypolimnetic waters which can support cold water fisheries.

Hypolimnetic aeration/oxygenation devices fall under three main categories including, mechanical agitation, air injection, and oxygen injection. Under each category there are several different types. The most important parameter for all of these classes is the oxygen transfer efficiency. The oxygen transfer efficiency can be described as two characteristics; the amount of oxygen that is absorbed into the water per a specific amount of input oxygen (%); and the amount of oxygen that is absorbed into the water for an amount of energy input to the system (lbs O_2/kwhr). These devices are reviewed in a Waterways Experiment Station report "Investigation and Discussion of Techniques for Hypolimnion Aeration/Oxygenation" by Holland and Tate, 1984.

5.6.1.1 Mechanical Agitation

Water is usually withdrawn from the hypolimnion through an intake pipe and discharged into a splash basin located either on-shore or on the water surface where additional agitation may be used and aeration occurs. This is shown in Figure 65. Aerated water is then re ned to the hypolimnion through a discharge pipe by gravity flow. Such a system is relatively inefficient in terms of oxygen transfer to the water in terms of the percent and pounds O_2/kwhr. Another problem associated with this method is the warming of hypolimnetic waters due to exposure to warm summer air.

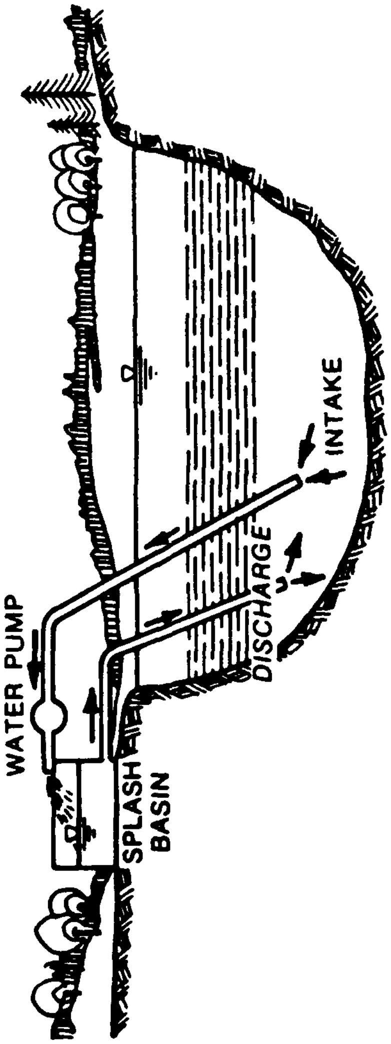
5.6.1.2 Air Injection Systems.

Air injection systems can be subdivided into three systems: bubbler, full air lift, and partial air lift designs.

5.6.1.2.1 Bubbler System Design

A bubbler consists of a land mounted air compressor which delivers air to the lake by way of bubbler diffusers located usually at the bottom of the lake. This system is analogous to the aquarium air pump aeration. Air is delivered to the lake by means of long pipes which contain a myriad of very small holes which diffuse the air or a series of diffuser stones. Oxygen is transferred to the water as the air bubbles raise to the water surface. These mechanisms would be laid along the bottom of the lake such that there would not be any interaction between the air and bottom sediments causing resuspension of the bottom sediments Such a system is shown in Figure 66. There are two major problems associated with a bubbler system. The first is that this type of system is generally inefficient in terms of oxygen transfer to the water in terms of percent and pounds O_2/kwhr. The other major problem relates to the fact that air bubbles break through the thermocline and cause mixing with the eplimnion resulting in warming of hypolimnetic waters. As the depth of water increases, there is a greater tendency to cause nitrogen supersaturation due to greater water pressures. Nitrogen supersaturation exceeding only small amounts can be fatal to fish and other aquatic organisms.

From: Holland and Tate, 1984

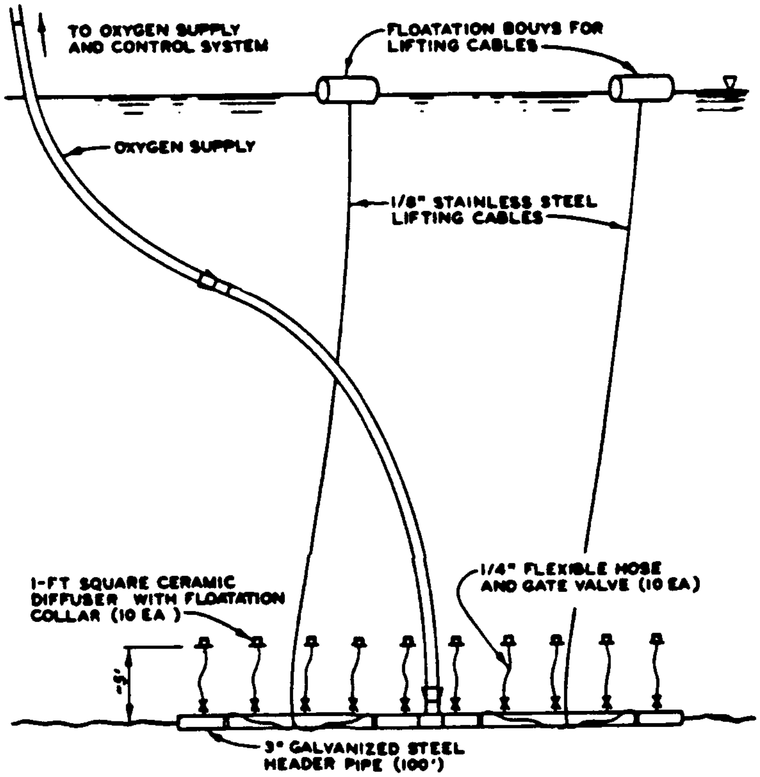


ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

MECHANICAL AERATION OF HYPOLIMNION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 65



From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

AIR-OXYGEN BUBBLER SYSTEMS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 66

5.6.1.2.2 Full Air Lift Designs

In these systems, air is injected near the bottom of the aerators. The air and entrained water plume then rises to near the lake's surface where the air separates from the plume and exits to the atmosphere and the water is returned to the hypolimnion. Many different designs exist as shown in Figures 67-71. The major drawbacks on the designs are the efficiencies and the possibilities of hypolimnion water warming.

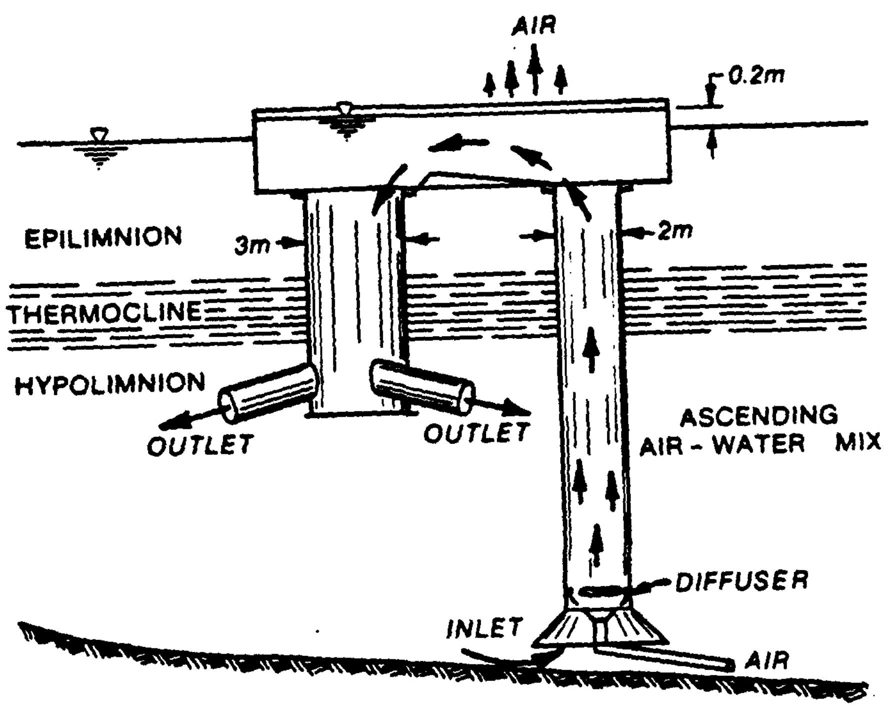
Figure 67 illustrates the system described by Fast (1971). The aerator consisted of concentric upwelling and downwelling pipes: air was released in the center (upwelling) pipe, and the resulting air/water plume rose to the lake surface. Fast, Lorenzen, and Glenn (1976) proposed modifications to this system to increase its efficiencies. Use of this system at Hemlock Lake, Michigan, increased hypolimnetic dissolved oxygen concentrations from 0 to 8 mg/l (Fast 1973a).

Bernhardt (1974) described the full air lift design, shown in Figure 68, which incorporated separate upwelling and downwelling pipes separated by a horizontal degassing chamber. Use of this aerator in Wahnbach Reservoir, West Germany, yielded one of the greater oxygen transfer efficiencies yet reported: 2.4 pounds O_2/kwhr, with a 50 percent absorption rate. The system also greatly reduced dissolution of iron, manganese, and phosphorus from sediments, while maintaining cold hypolimnion waters.

Both Smith, Knauer, and Wirth (1975) and Bengtsson, et al. (1972) described hypolimnetic aerators similar in design to that of Bernhardt. The aerator designed by the former, shown in Figure 69, was constructed of inexpensive materials and had flexible outlet tubes and styrofoam flotation. The design also had an upwelling pipe containing a patented helical insert which purportedly increased oxygen transfer efficiency. Bengtsson, et al. (1972), described two full air lift systems which were used to aerate Lakes Tullingesjon, and Jarlasjon, Sweden. The Lake Tullingesjon aerator, shown in Figure 70, had a 1.3-foot diameter upwelling tube which discharged horizontally into a degassing chamber. It also had four 1.6-foot diameter outlet pipes for flow distribution. Approximately 530 SCFM of compressed air were injected. Although the lake was aerated for 2-1/2 months, hypolimnetic dissolved oxygen concentrations failed to increase above 0.0 mg/l. The Lake Jarlasjon system (Figure 71) differed from that of Lake Tullingesjon in that, (a) the upwelling pipe was 2 feet in diameter and discharged in a vertical overflow fashion into the degassing chamber, (b) ten outlet pipes of 1.6-foot diameter were used, and (c) 789 SCFM of air were injected; hypolimnion dissolved oxygen concentrations of more than 8 mg/l were attained. The efficiency of each of these two Swedish systems, however, was greatly reduced due to the very high air injection rates coupled with the relatively small diameter of the upwelling pipe.

5.6.1.2.3 Partial Air Lift Designs

Partial air lift systems are those which aerate and circulate hypolimnetic water by air injection, but do not lift the air/water plume so high; consequently, water is not upwelled to the surface. Instead, water and air separate well below the lake's surface, water is returned to the hypolimnion, and air is wasted to the atmosphere.



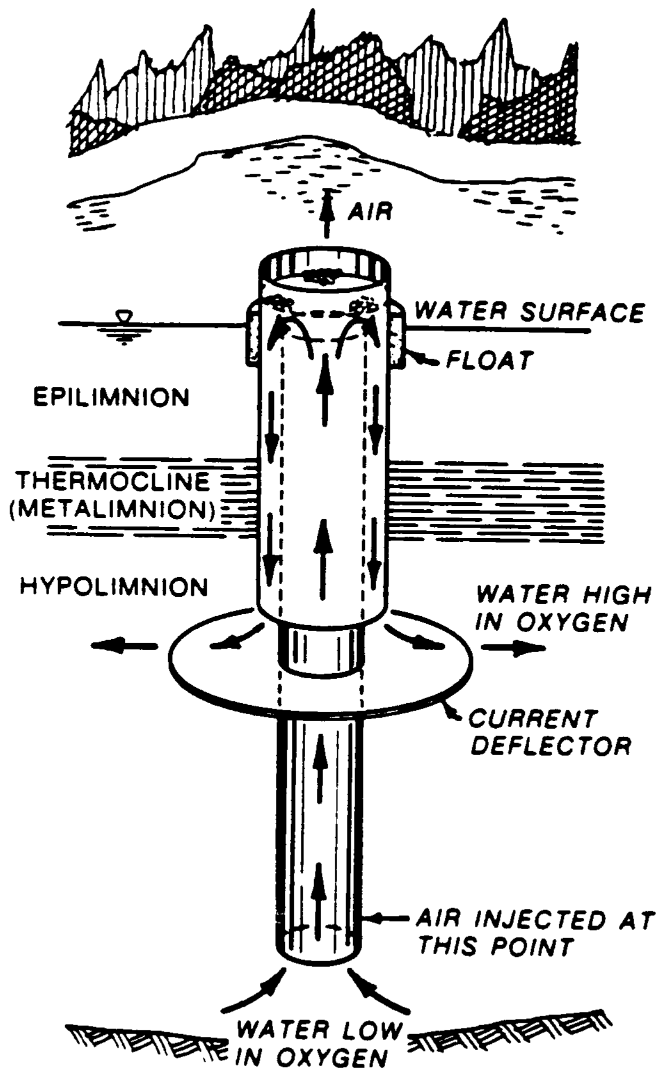
From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FULL AIR LIFT HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 67

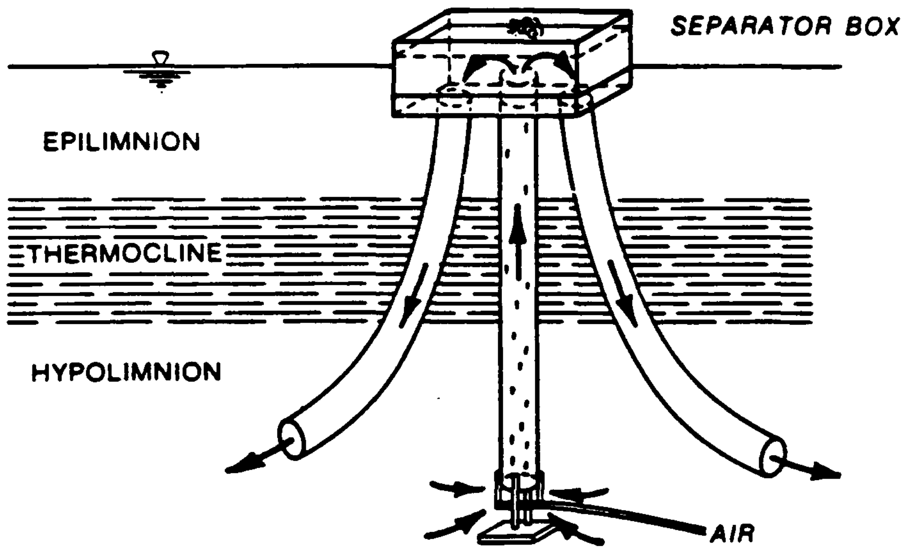


From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FULL AIR LIFT HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991



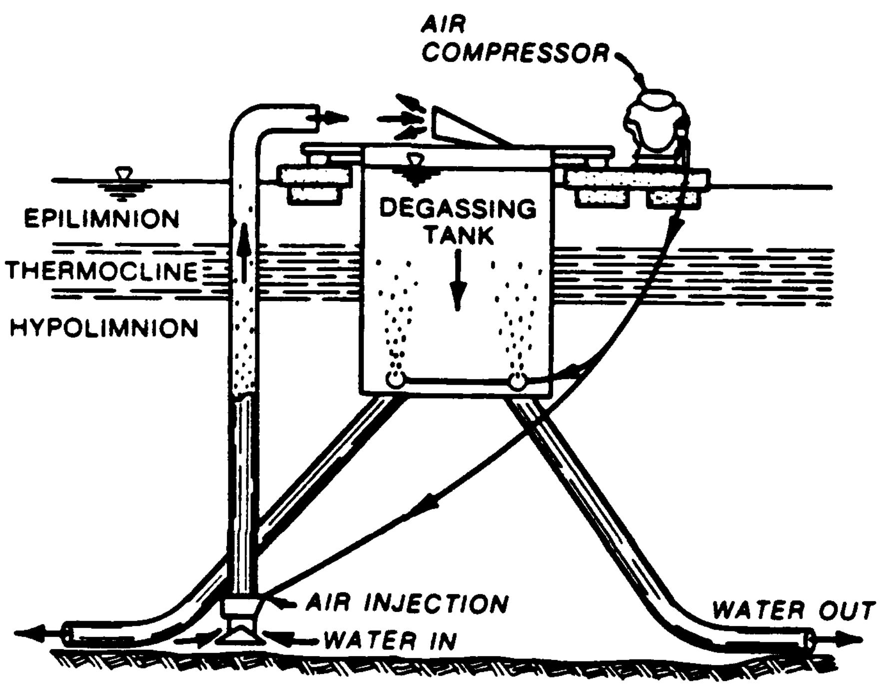
From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FULL AIR LIFT HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 69



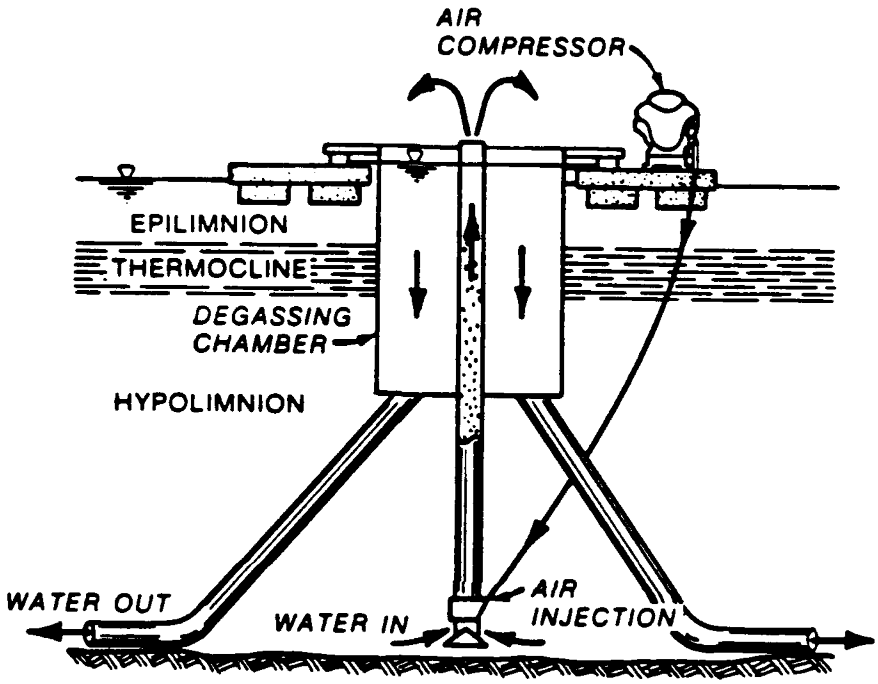
From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FULL AIR LIFT
HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 70



From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FULL AIR LIFT HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 71

The partial air lift designs appear to be much less efficient than the full air lift designs. Although the partial air lifts have greater effluent oxygen concentration, they aerate less water volume and total oxygen dissolved is less than full air lift designs. Most energy used to compress the air is lost in the waste air discharge line, and the air does not expand greatly while in contact with water. Two partial air lift designs are shown in Figures 72 and 73.

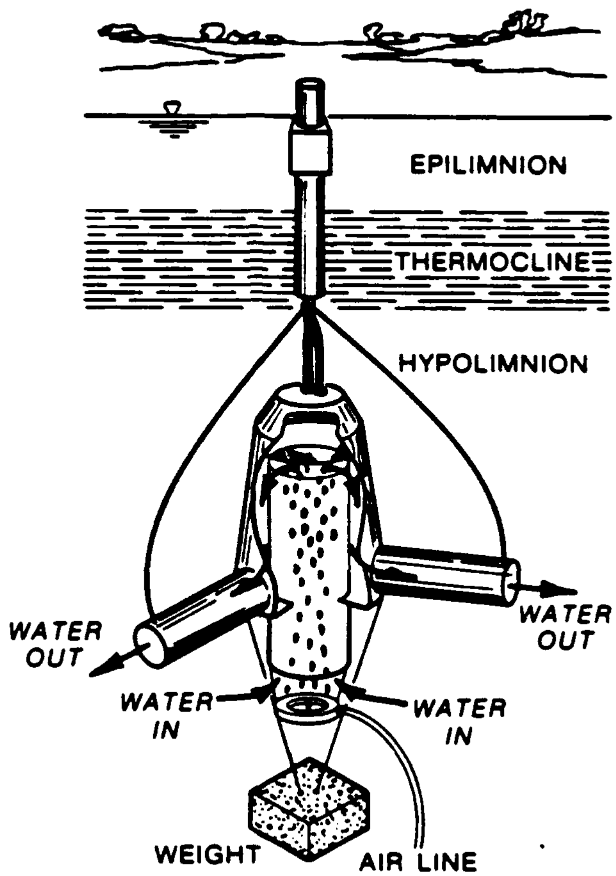
Bjork (1974) and Fast, Dorr, and Rosen (1975) described European and North American operation of these systems, respectively, in detail. Figure 72 shows a system in which air released from a diffuser at the bottom of the aerator causes a hypolimnetic water plume to upwell through a 15-foot high, 78-foot diameter chamber. At the top of this chamber, the waste air was vented to the atmosphere and the water flowed through six outlet pipes. A waste gas valve maintained a pressurized pocket of gas at the top of the aerator to check the release of water through the venting pipe. Fast (1973b) reported that this system provided 1.2 pounds O_2/kwhr to the hypolimnion of Lake Waccabuc, New York, with 10.6 percent of injected oxygen absorbed. Fast, Dorr, and Rosen (1975), however, reported that the use of this system resulted in significant increases in dissolved N_2 saturations with respect to surface pressures.

Speece, Rayyan, and Givler (1975) suggested a partial air lift system shown in Figure 73, which is similar to the Lake Waccabuc system discussed above except that it has no valve to check release aerated waters through the vent pipe. Consequently, gas and water may be pumped through the gas discharge line. Provisions may have to be made to return this water to the hypolimnetic water which otherwise would be pumped into the epilimnion.

5.6.1.2.4 Hybrid Systems

The two additional systems presented below represent variations on the full and partial air lift systems. The first is a "standpipe" aerator described by Bernhardt (1967), the original aerator used at Wahnbach Reservoir, West Germany, and later replaced by the full air lift design of Bernhardt discussed above. The structural design of the system as shown in Figure 74 resembles that of a full air lift system; however, most of the water is upwelled only to the level of the outlet arms rather than to the surface. Conceptually, this standpipe device is very similar to a partial air lift system; nonetheless, it achieved an oxygen transfer efficiency of 2.1 pounds O_2/kwhr, with an injection rate of 142 SCFM and an oxygen absorption efficiency of 50 percent.

The other type of systems are termed "down flow air injection" systems. The basis of these systems (Speece, 1970) is a mechanical pump which transports water downward in a vertical pipe while air is injected below the pump. The downward velocity of the water, which is greater than the bubble-rise velocity, sweeps the air downward into the hypolimnion where the air and water separate. The advantages of this technique are increased air/water contact time for a given length pipe, exposure of the bubbles to a continuously increasing oxygen saturation gradient, and requirement of a low pressure air compressor. These factors tend to increase the percentage of oxygen absorbed from the air. However, the large water velocity required would also complicate air/water separation, and additional energy is required

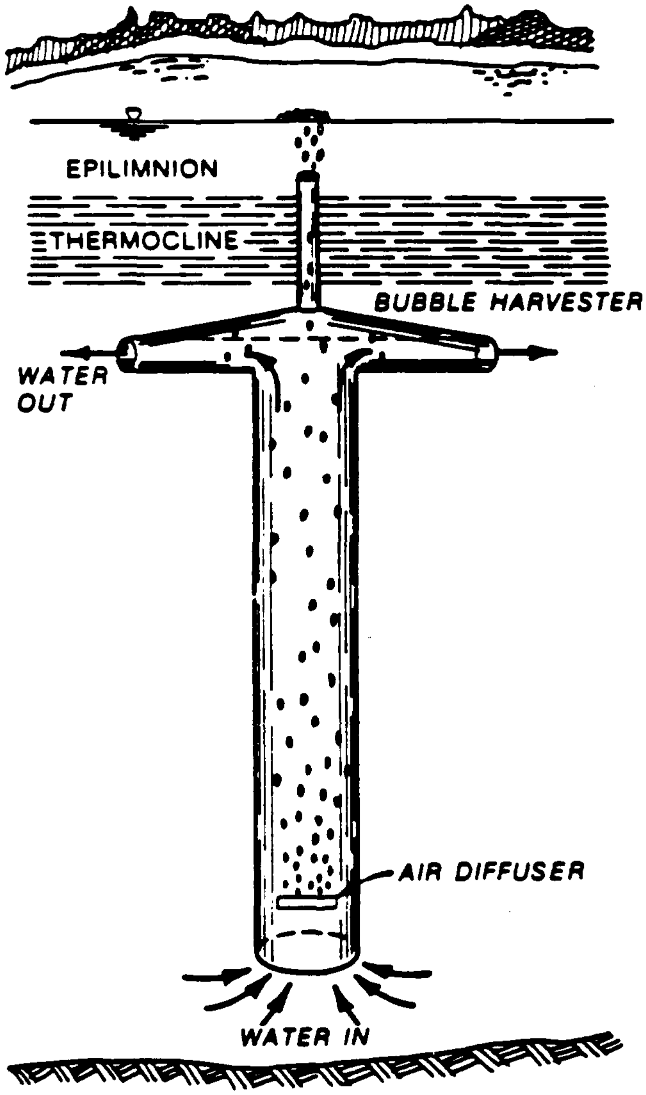


From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

PARTIAL AIR LIFT HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991



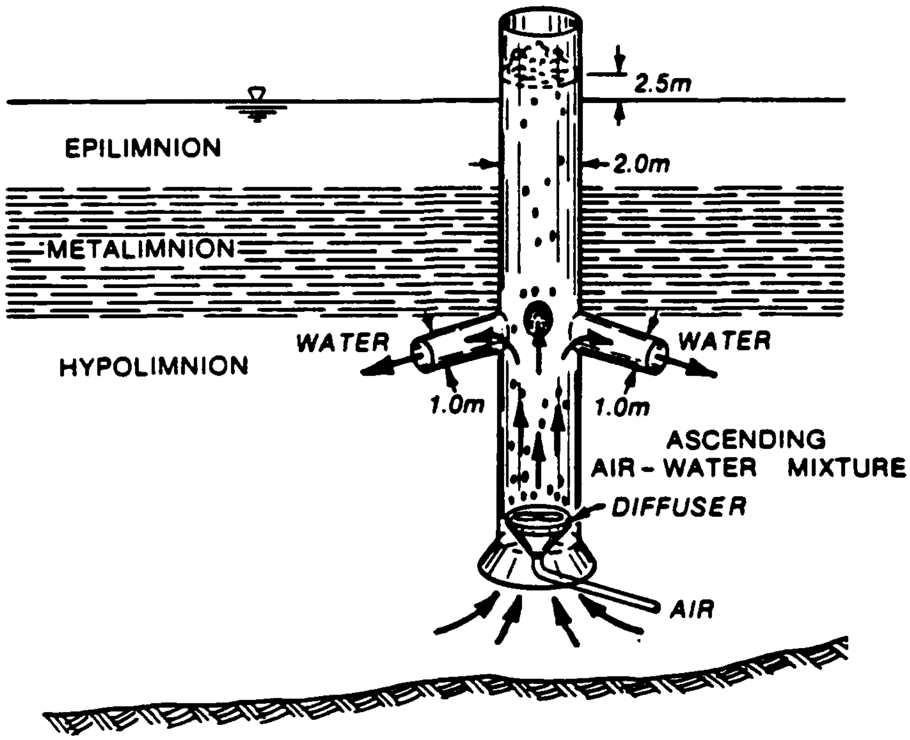
From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

PARTIAL AIR LIFT HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 73



From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISANCE REPORT

STANDPIPE HYPOLIMNETIC AERATOR

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 74

to mechanically pump the water. Furthermore, dissolved nitrogen gas concentration will be greatly increased by these systems, and unacceptable nitrogen concentrations may occur. Speece's first system (Speece, 1971) incorporated both downflow and air lift features as shown in Figure 75. A subsequent system (Speece, Rayyan, and Givler, 1975) was similar in design but allowed venting of waste gases to the atmosphere. Possible nitrogen supersaturation could be of considerable concern for potential fisheries impact.

5.6.1.3 Pure Oxygen Injection Designs

Pure oxygen injection systems use pure gas or liquid oxygen to aerate the hypolimnion directly.

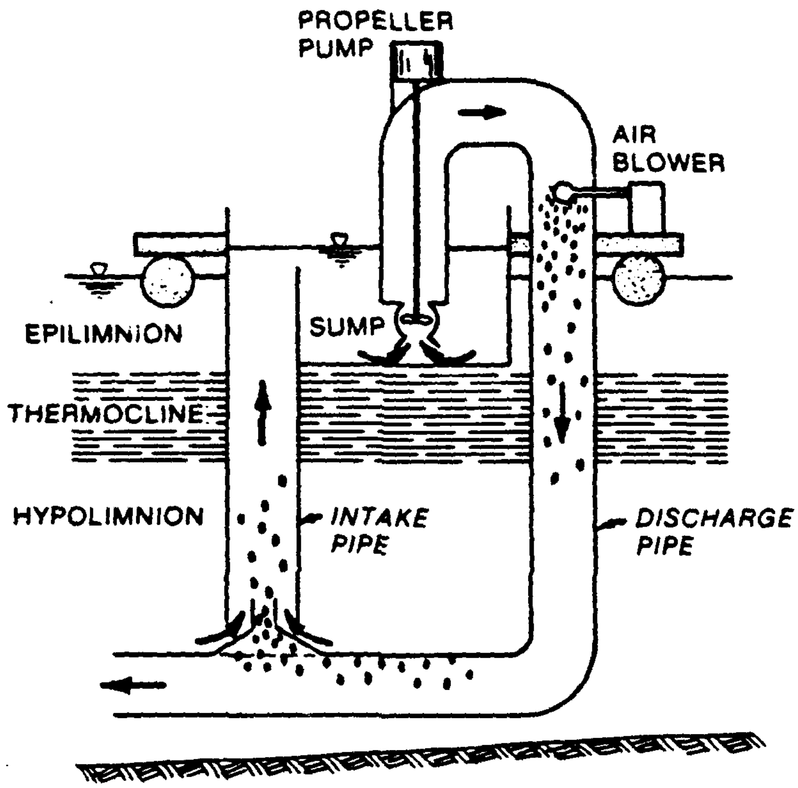
5.6.1.3.1 Side-stream Pumping

Side-stream pumping (SSP) was one of the first successful means of hypolimnetic aeration with pure oxygen as demonstrated by Fast, Overholtz, and Tubb (1975). The system, shown in Figure 76, is conceptually simple. Hypolimnetic waters are withdrawn through a pipe by a shore-based pump and then oxygenated in the discharge line under high pressure. The combination of pure oxygen and high discharge line pressure results in the oxygen being almost totally dissolved before the hypolimnetic waters are returned into the hypolimnion. Fast, Overholtz, and Tubb (1975) successfully used this system at Ottoville Quarry, Ohio. Oxygen concentrations increased from zero to 8 mg/l in 1973 and to 21.5 mg/l (seems high and questionable) in 1974 (Overholtz, 1975). Hypolimnetic temperatures were observed to increase 5°C and 9°C in 1973 and 1974, respectively, due to mixing induced as a result of the oxygenation procedure. The system had a 5-hp water pump and maximum input capacity of about 50 pound/day. Fast and Lorenzen (1976) computed an oxygen absorption efficiency for this system of 0.5 pound O_2/kwhr, assuming an energy consumption rate of 800 kwhr/ton of liquid oxygen.

A second SSP test at Attica Reservoir, Attica, New York was unsuccessful. The SSP system at Attica was larger and the reservoir much shallower than at Ottoville. Although only 1.3 percent of the hypolimnetic water volume during 1973, and 0.7 percent during 1974, was pumped through the system each day, the reservoir was rapidly destratified each year. In Ottoville Quarry, 1.3 percent of hypolimnetic volume was pumped per day but thermal stratification was maintained, indicating that much reduced water velocities and flow rates are required to maintain thermal stratification in shallow lakes. The Attica system was designed to dissolve 60 pounds of oxygen/day, for an efficiency of 0.17/pound O_2/kwhr.

5.6.1.3.2 Other Pure Oxygen Designs

Speece has proposed the following two methods for hypolimnetic oxygenation; (a) the use of pure oxygen rather than air in the downflow aerator described above (Speece 1970, 1971; Speece, Rayyan, and Givler, 1975) and (b) a system which employs the injection of pure oxygen from coarse-bubble diffusers at some depth within the hypolimnion (Speece 1971, 1973, 1975). Method (a) is shown in Figure 77 and consists of a cone-shaped device suspended within the hypolimnion. A pump forces water downward and pure



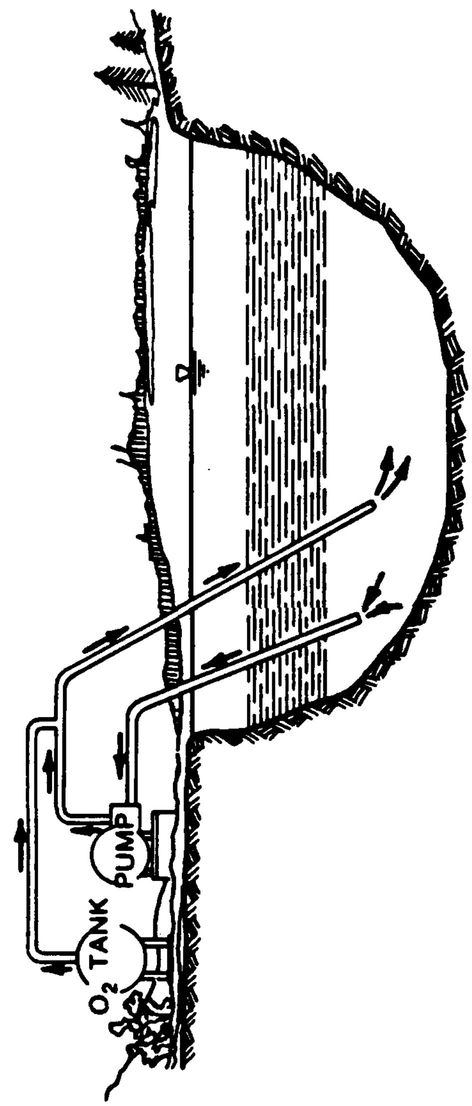
From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

DOWNFLOW AIR INJECTION SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 75

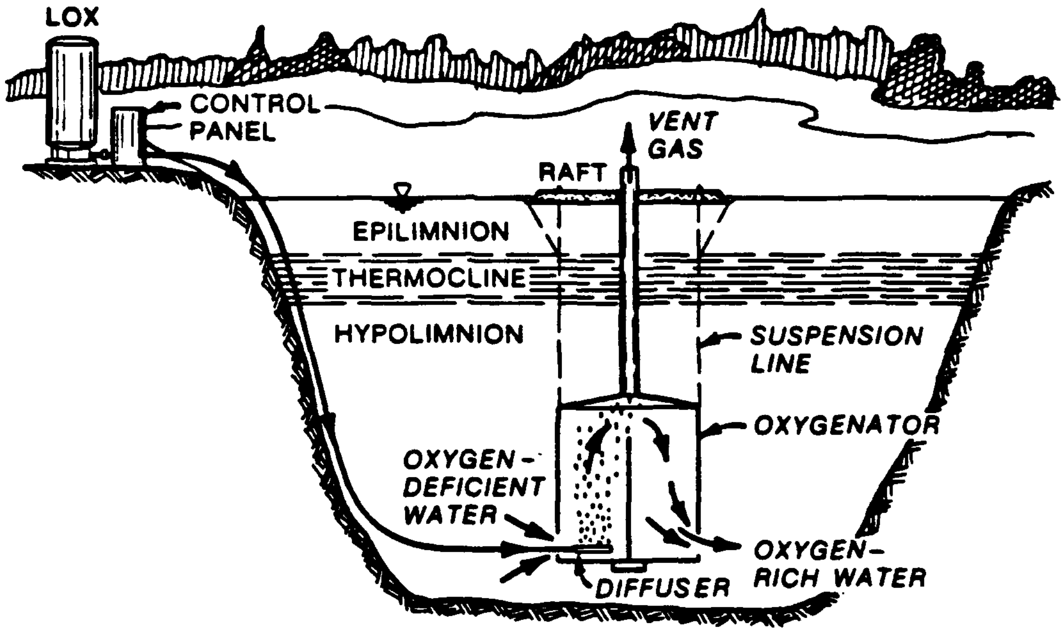


From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SIDE STREAM PUMPING HYPOLIMNETIC OXYGENATION SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991



From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

HYPOLIMNETIC OXYGENATION SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 77

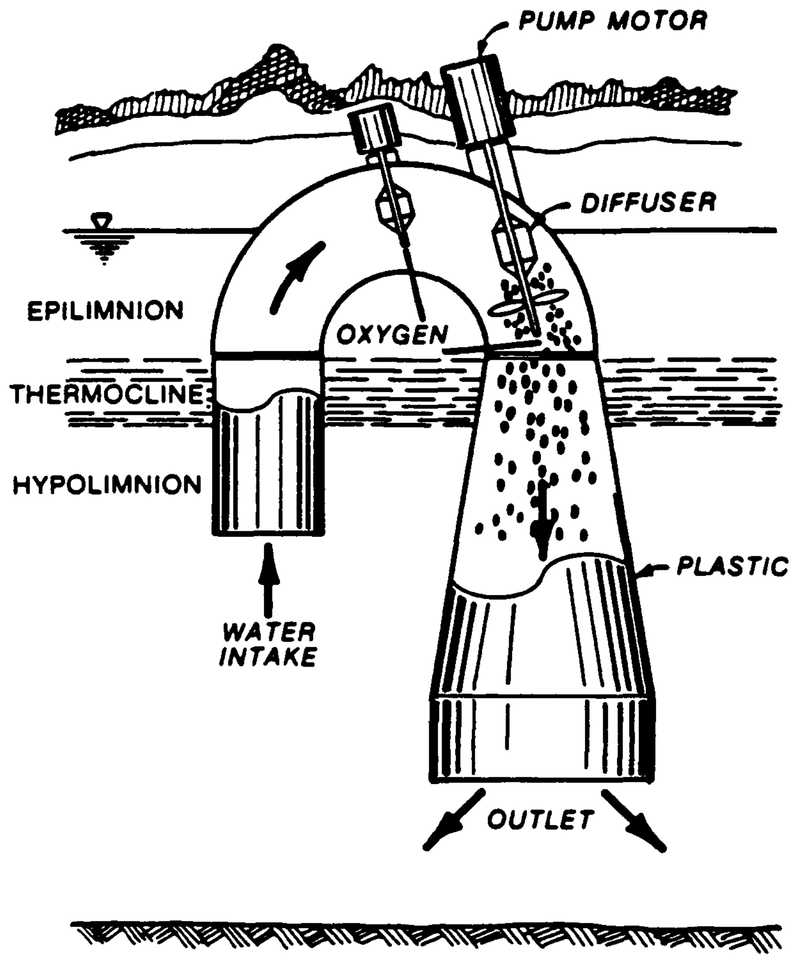
oxygen is diffused below the pump. Bubble contact time is lengthened as with the downflow air injection. High water velocity in the throat 8 fps $\pm$ 2 fps (2.4 m/s$\pm$0.6 m/s) prevents gas bubbles from escaping through the top of the funnel; instead, bubbles are forced under the lower rim after about 15 seconds of contact time. By that time, much of the oxygen has diffused out of the bubble and into the water, while nitrogen gas has diffused into the bubble. Waste bubbles then rise to surface. This waste stream will entrain water and cause an upwelling. This upwelling may penetrate the thermocline in some cases and therefore be unacceptable. Method (b) uses a deep oxygen bubble injection method of hypolimnetic oxygenation. This technique involves injection of high purity oxygen from coarse bubble diffusers at some depth within the hypolimnion. This is similar to that for air as shown in Figure 68. If the hypolimnion is deep enough (e.g., 60 ft (18.3m) of hypolimnetic height), then most of the bubbles will be dissolved before reaching the thermocline. If the gas volume is small, according to Speece, the bubbles will "uncouple" from the water at the thermocline and rise through the thermocline to the lake's surface, while the oxygenated hypolimnetic water will partially mix with warmer thermocline water and form a "sandwich layer" at the base of the thermocline, spreading out from a plume area. If the rate of gas input is too great, upwelled hypolimnetic water may penetrate the thermocline and excess mixing with shallow water may occur.

Deep oxygen bubble injection may not be feasible if uncoupling is not complete or if oxygenated water does not mix throughout the hypolimnion, or both. This situation could lead to a sandwich layer of high oxygen content and an oxygen depleted zone near the lake bottom. This method was used successfully in Hamilton Harbor, Ontario on Lake Ontario. However, the hypolimnetic depth was less than 60 feet and the bubbles broke the surface indicating less than 100 percent efficiency.

The last system is shown in Figure 78 and described by Seppanen (1974). This device was used to oxygenate two Finnish lakes. The aerator resembles the downflow air injection system described above. Water is withdrawn from the hypolimnion and discharged to the hypolimnion at high velocities by a mechanical water pump. Oxygen is injected above the pump and the water forced the bubbles into the hypolimnion. Reported problems consist of gas pocket formation in the top of the tube's arch possibly caused by large bubb: upwelling caused by bubble coalescence within the downflow tube.

There are no new or more efficient methods for air oxygenation reported in the literature. All of the above air technologies could be used with pure oxygen but there would be no significant gains. The significant costs of using oxygen would not be economically offset by the additional amounts of oxygen dissolved over using air. Large amounts of oxygen would be wasted to the atmosphere.

The oxygen transfer efficiency can be calculated two ways; the oxygen transfer efficiency in pounds O_2/ kwhr and amounts of oxygen absorption in percent. This information for some of the above described systems is presented in Table 35. The above information is limited to the specific nature of the site, data, and needs and must be viewed with reservations. It appears that partial air lift systems are less efficient than full air lift systems. Although they have greater effluent dissolved oxygen concentrations, they aerate less water volume and have less total bubble contact time and less total oxygen dissolved than full air lift systems. Further, a majority of the



From: Holland and Tate, 1984

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ISTERI OXYGEN INJECTION SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 78

Table 35

Oxygen Transfer Efficiencies for Nine Hypolimnetic Aeration/Oxygenation Systems (data from Lorenzen and Fast 1977 and Pastorok et al. 1982)

Site of Aeration	Air/O_2 Injection Rate, cfm	Oxygen Transfer Efficiency lbs O_2/kwhr	Oxygen Absorption %	Ambient Oxygen Concentration	Reservoir Aerator Depth, ft Max	Min	Mean	Aeration Duration Month	Reservoir Volume acre-ft	Source of Data
				Full Air Lift System						
Wahnbach I	141.9	2.1	50	<4	141	63	--	4.3	33,745	Bernhardt (1967)
Wahnbach II	317.8	2.4	50	<4	141	63	--	4-60	33,745	Bernhardt (1974)
Mirror	15.9	0.7	9-14	0	43	25	42	1-2	324	Smith et al. (1975)
Larson	15.9	0.7	14-23	<7.5	39	13	39	1.5-5	153	Smith et al. (1975)
Jarlasjön	805.1	0.7	10.3	0	79	31	79	4.2	6,323	Bengtsson et al. (1972)
				Partial Air Lift System						
Waccabuc	280.0	1.2	10.6	4	43	--	43	3	31,285	Fast (1973a,b)
				Oxygen Injection System						
Ottoville	3.9	0.5	>95	>8	59	--	59	3	51	Fast et al. (1975b)
Spruce Run 1973	5.3	0.8-1.0	30-41	<0.5	43	--	40	2	--	Whipple et al. (1975)
Spruce Run 1974	5.3	0.4-0.8	18-30	<4	43	--	40	5	--	Whipple et al. (1975)

energy required to compress the air and pump it to depth is often lost due to the venting of large quantities of waste gas. If large amounts of oxygen are needed and high efficiencies (%) can be maintained, then pure oxygen systems would be preferable.

5.6.1.3.3 Goals for Oxygenating the Hypolimnion of Onondaga Lake

The main reason for artificially maintaining oxygen in the hypolimnion of Onondaga Lake is to increase the usability of the water and to prevent anoxic conditions. With dissolved oxygen concentrations above 4 mg/l, fisheries could be established. Above 6 mg/l, cold water fisheries could once again be established supporting salmonid species. Above 2 mg/l would eliminate the solution of most metals (iron and manganese) from the sediments (Bernhardt, 1974, Holland & Tate, 1984). The effect on mercury releases is unknown. Oxygenation of hypolimnetic waters would eliminate or reduce the formation of hydrogen sulfide, methane, and ammonia. The most important goal would be to eliminate, reduce, and control nutrient recycling (carbon, nitrogen, and phosphorus) from the sediments.

When accomplishing the above goals, various aspects must be considered. These include destroying the lake stratification, increasing the temperature of the hypolimnion above that which occurs naturally, increasing the hypolimnetic volume, increasing the dissolved nitrogen concentration, and disturbing or mixing the bottom sediments. To obtain the goal of maintaining an oxygenated hypolimnion, some of these aspects might have to be relaxed to levels that may be acceptable but not necessarily desirable.

5.6.1.3.4 Hypolimnetic Oxygen Demand for Onondaga Lake

The most accurate estimates of hypolimnetic oxygen consumption are derived from observing the rate of oxygen depletion following the onset of thermal statification. The hypolimnetic oxygen depletion rate following thermal stratification in the spring-summer is probably preferable, but the fall-winter stagnation may also be used in lakes with ice cover. It can be expected that during the winter the consumption rate would be lower than those during the summer because colder temperatures restrict chemical and biological activities. These methods are limited to one or two periods of the year. These periods can be very short in those lakes with high depletion rates such as Onondaga Lake. For example, if the depletion rate is 1 mg O_2/l/day and the water is saturated with oxygen when thermal stratification develops, then the oxygen will be essentially absent within 2 weeks.

The data needed to calculate the rate of oxygen depletion include depth profiles of temperature and oxygen during closely placed time periods at the onset of stratification. For a better analysis, sampling should be performed as often as possible at the beginning of stratification. Also, it is beneficial to obtain more samples in the depth profiles because of the variability in the system due to weather and other factors. Also profiles for more than 1-year should be checked. The other piece of information needed is the distribution of lake volume as a function of depth.

From the temperature profiles, a division between the eplimnion and hypolimnion can be approximated. The total hypolimnetic oxygen content can be calculated as a mass of total oxygen or a volume weighted average oxygen concentration in mg/l. In each case, the concentration at a specific depth is multiplied by the volume of the slice of the lake water it represents. The

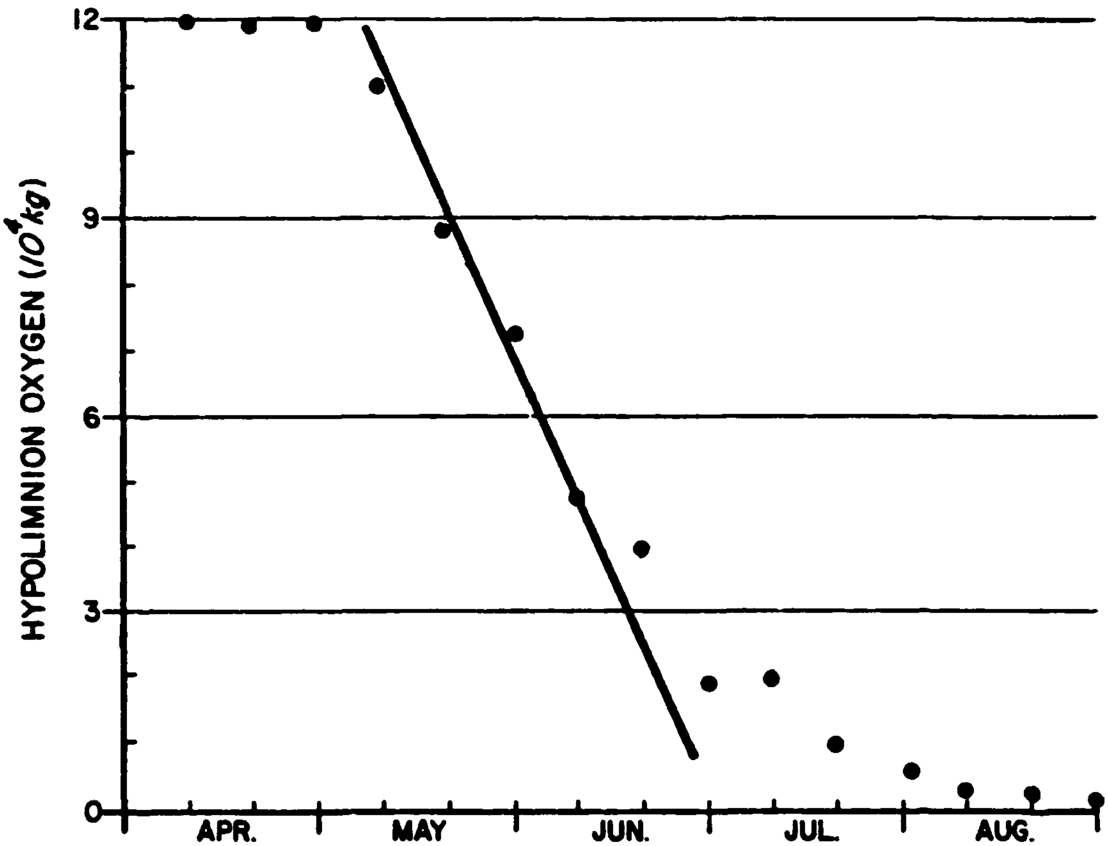
hypolimnetic oxygen content is plotted against time. Figure 79 illustrates an idealized case for total oxygen mass. Usually these cases are a great deal more complex. Figure 80 illustrates actual earlier data for Onondaga Lake. Note the variability in the data. Before 1986 stratification was influenced by industrial discharges. These plots yield a curve from which the rate of oxygen depletion can be calculated. The depletion rate in kg/day is calculated for the slope of a regression line through selected data points. Generally, the points which give a maximum depletion rate are chosen. The rate of depletion is concentration dependent and decreases as the hypolinmetic oxygen content approaches zero. In some cases the oxygen consumption rate is underestimated and increases during aeration.

The increases could possibly be attributed to increased water circulation caused by aeration, the increase in water circulation through the sediments by reestablishing the benthic community, and increased respiration and decomposition due to temperature increases. Hypolimnetic aeration has caused hypolimnetic temperature increases ranging from a few degrees to more than 9°C. This is due to injection of warm air or oxygen, exposure of cold hypolimnetic waters to the surface air temperatures, and entrainment of warmer eplimnion waters.

Figure 81 is the most recent bathymetric map of Onondaga Lake (Upstate Freshwater Institute, April 1988). Table 36 presents volume, area, and average depth as a function of depth. Figures 82 and 83 present volume and surface area in graphical form, respectively (Upstate Freshwater Institute). The old data from 1968 are also shown and it is interesting to note changes due to sedimentation in the lake. These curves are used in conjunction with the dissolved oxygen profiles to determine the oxygen depletion rates.

Table 36 Onondaga Lake Hypographic Data
Based on 1987 Survey

Depth Meters	Averaged Depth Meters	Percent Averaged Depth	Area 10^6 Meter ^{2}	Percent Area	Volume 10^6 Meter ^{3}	Percent Volume
0	10.9	100	12.0	100	131	100
1	10.8	99	11.0	91.7	119	90.8
2	10.5	96.3	10.4	86.7	109	83.2
3	10.1	92.7	9.74	81.2	98.5	75.2
4	9.5	87.2	9.33	77.8	89.0	67.9
5	9.0	82.6	8.89	74.1	79.9	61.0
6	8.4	77.1	8.52	71.0	71.2	54.4
7	7.7	70.6	8.13	67.8	62.8	47.9
8	7.1	65.1	7.78	64.8	54.9	41.9
9	6.4	58.7	7.35	61.2	47.3	36.1
10	5.8	53.2	6.98	58.2	40.2	30.7
11	5.1	46.8	6.51	54.3	33.4	25.5
12	4.4	40.4	6.10	50.8	27.1	20.7
13	3.8	34.9	5.60	46.7	21.3	16.3
14	3.1	28.4	5.13	42.8	15.9	12.1
15	2.4	22.0	4.56	38.0	11.1	8.5
16	1.8	16.5	3.87	32.3	6.8	5.2
17	1.2	11.0	2.89	24.1	3.5	2.6
18	0.7	6.4	1.65	13.8	1.2	0.9
19	0.3	2.8	0.48	4.0	0.12	0.1
19.5	0	0	0	0	0	0



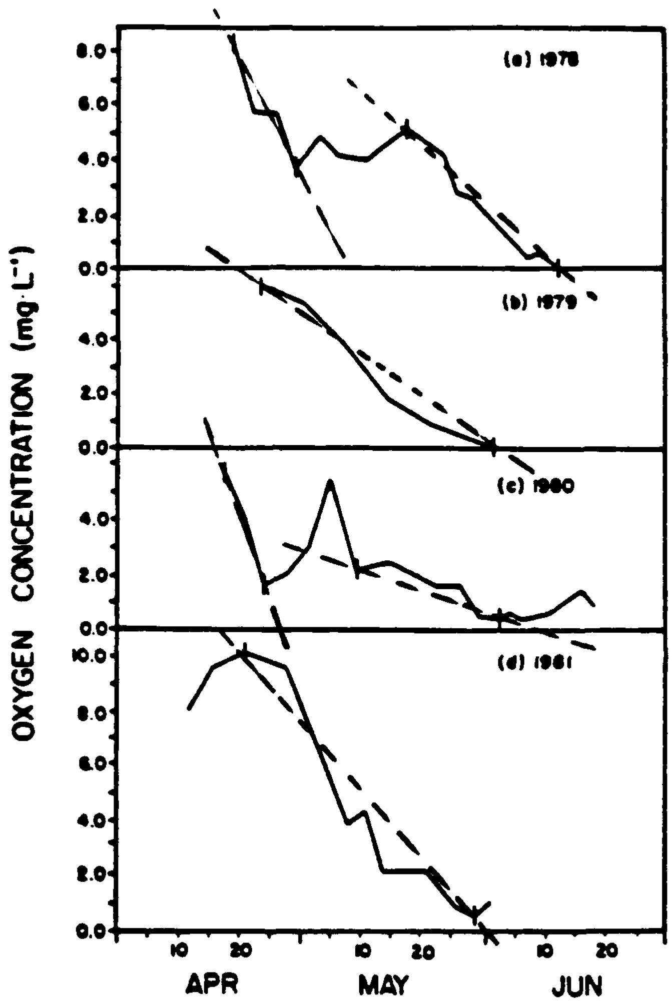
From: Lorenzen and Fast, 1977

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

EXAMPLE OF OXYGEN DEPLETION RATES DATA

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 79



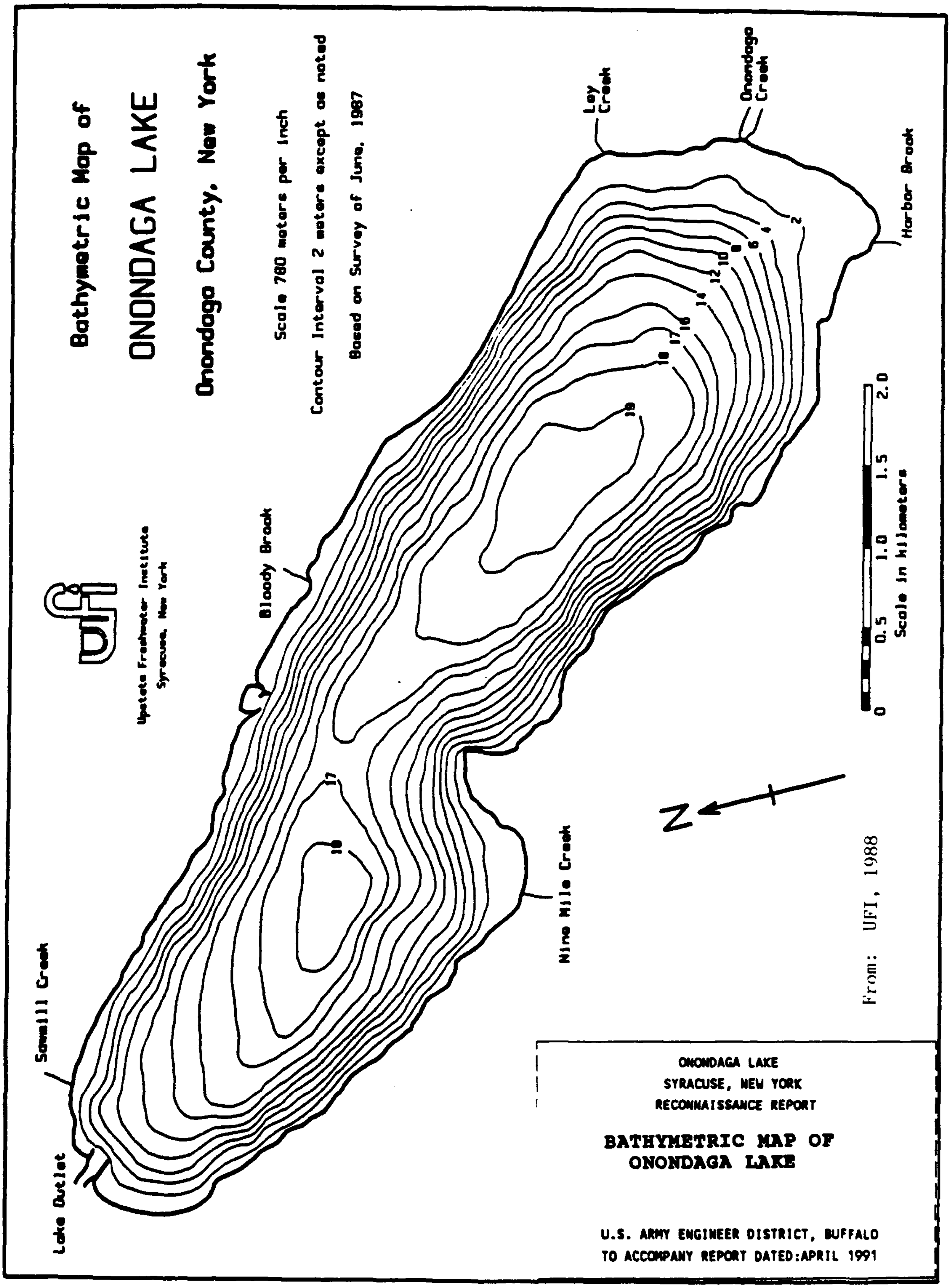
From: Effler, Perkins, and Brooks, 1986

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

VOLUME WEIGHTED MEAN CONCENTRATION OF DO IN HYPOLIMNION-ONONDAGA LAKE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 80



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

BATHYMETRIC MAP OF ONONDAGA LAKE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 81

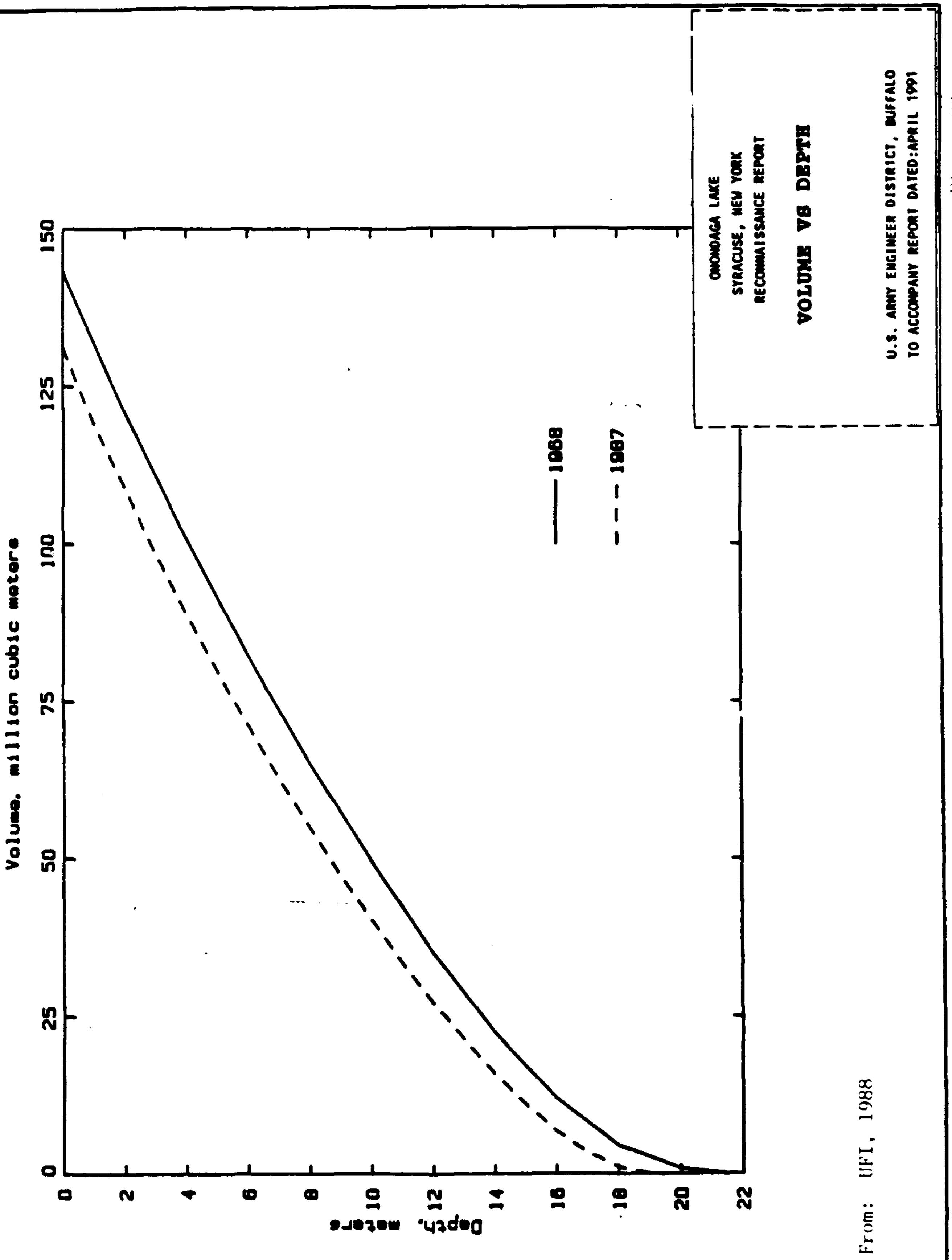

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT
VOLUME VS DEPTH
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991
Volume, million cubic meters
Depth, meters
1988
1987
0
25
50
75
100
125
150
0
2
4
6
8
10
12
14
16
18
20
22
From: UFI, 1988

Figure 82

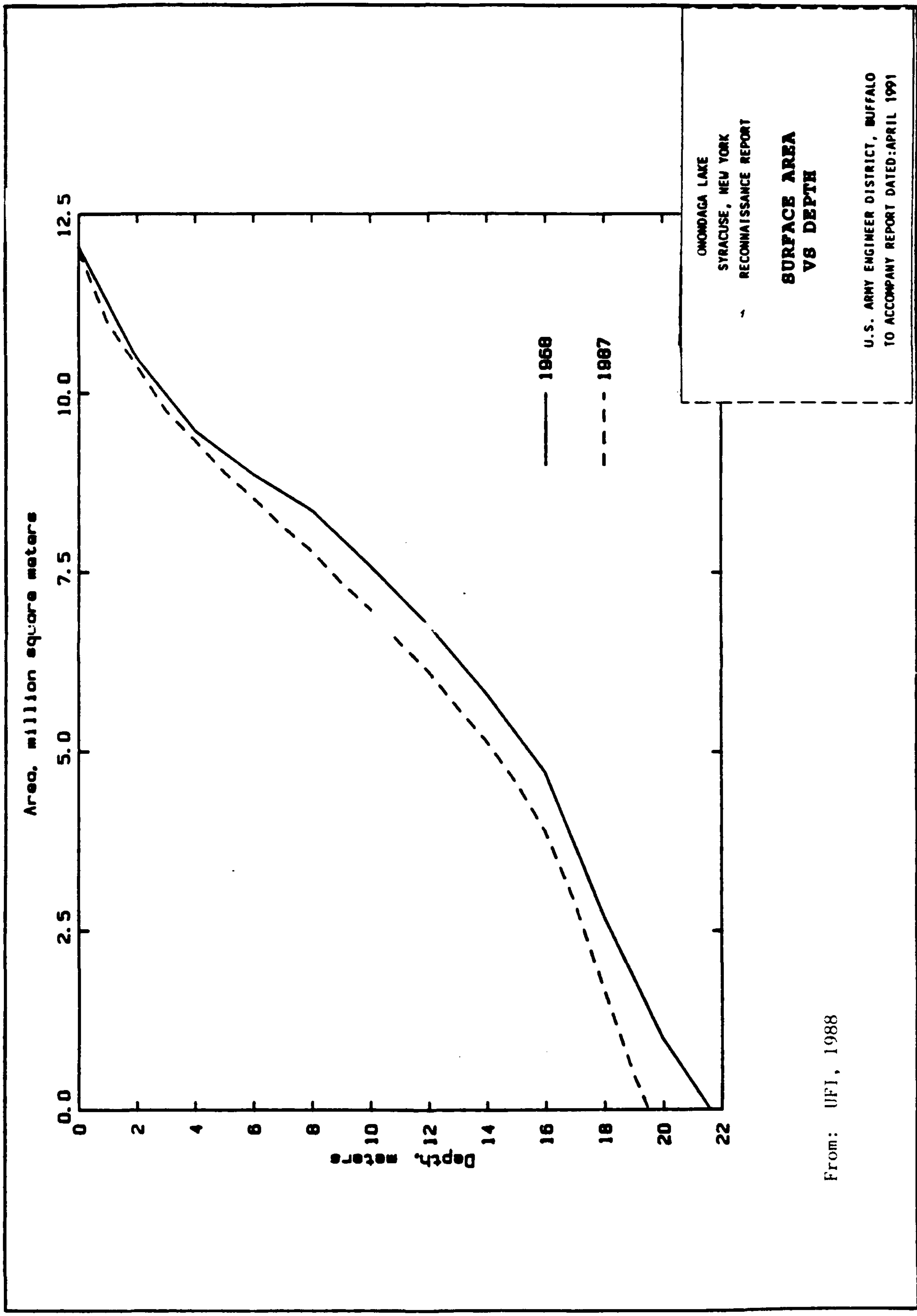

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT
SURFACE AREA
VS DEPTH
U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991
Area, million square meters
Depth, meters
1968
1987
0.0
2.5
5.0
7.5
10.0
12.5
0
2
4
6
8
10
12
14
16
18
20
22
From: UFI, 1988

Figure 83

Table 37 UFI Hypolimnetic Oxygen Depletion Rates

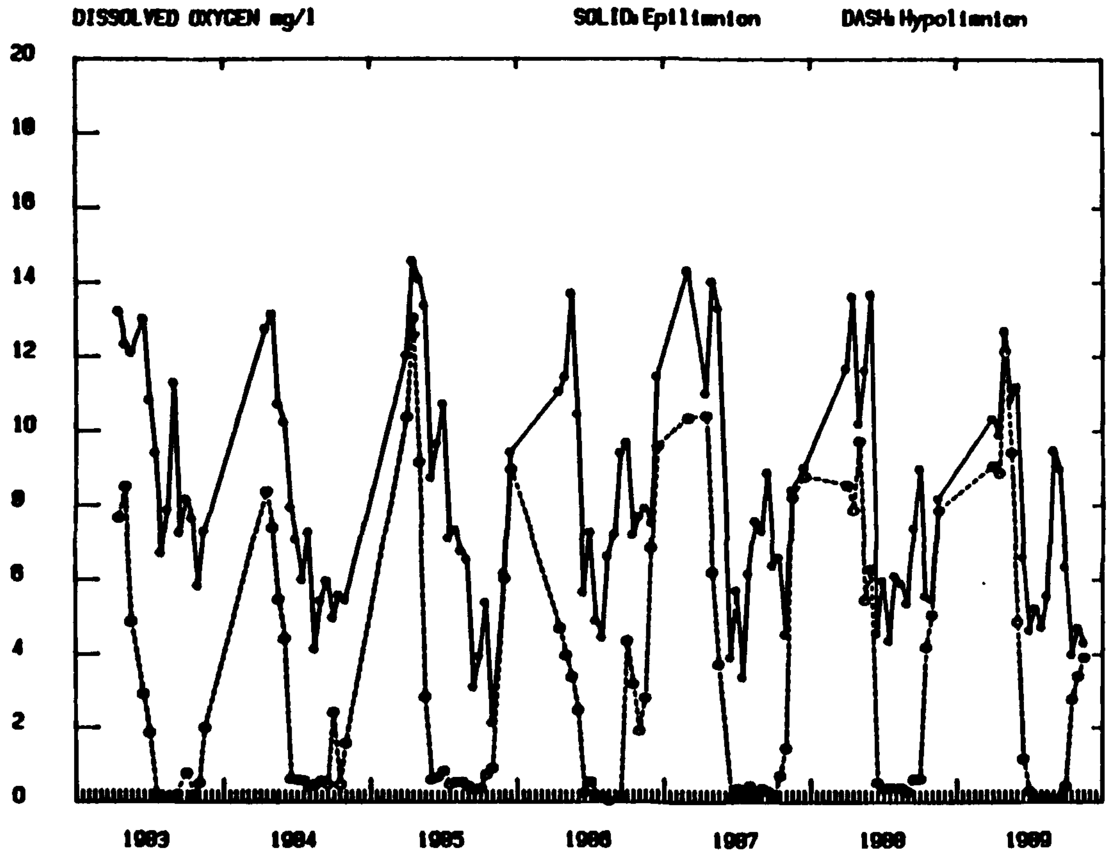
Year	gms/meter2/day	mg/liter/day	pounds/minute
1981	1.46	0.252	15.5
1985	1.35	0.233	14.3
1987	1.44	0.248	15.3
1988	1.23	0.212	13.0
1989	1.05	0.181	11.1
1990	1.06	0.183	11.3

Figure 84 presents dissolved oxygen concentration for the epilimnion and hypolimnion as calculated from the Onondaga County Sampling program (Stearns & Wheler Onondaga Lake Monitoring Program, April 1990). Depletion rates for the various years can be calculated from their data. The hypolimnion is taken as the water below the 10 meter depth. The oxygen deficit rates calculated from the Upstate Freshwater Institute's sampling program are shown in Figure 85. Note the deficit is presented as gm m^{-2} d^{-1} and must be converted to mg/l/day (equivalent to gm m^{-3} d^{-1}) using average depth data from Table 24. As in the previous case, the hypolimnion is taken as that water below the 10 meter depth. Table 37 presents the conversion. Figure 86 shows the oxygen depletion rates for Figures 84 and 85. The Upstate Freshwater Institute data are shown by x's and the Onondaga County data by o's. The number above the symbols indicate the years. Obviously, there is much variation frcm year to year in the data. Also picking different thermocline depths could influence the deficit rates, so temperature profile data must be interpreted carefully. Since the oxygen data were already volume weighted averaged for the hypolimnion at 10 meters, these deficit and oxygen values are used at this time. Table 38 was taken from "A Guide to Aeration/Circulation Techniques for Lake Management" by Tetra Tech, Inc. January 1977. Upstate Freshwater Institute values have been added. Values for Onondaga Lake are high, however, reasonable when compared to other lakes or reservoirs. The total oxygen deficit for the volume of the hypolimnion appears to be excessive. Values for years prior to 1988 could be expected to be somewhat higher because of the aggravated stratification caused by industrial effluent containing high chloride concentrations.

The actual deficit used (11.2 pounds O_2 per minute) is taken as an average of the last 2 years values from the Upstate Freshwater Institute data.

This value can change from year to year depending largely on weather and various lake conditions. There is an indication in the literature that the tendency is to underestimate the amount (Holland and Tate, 1984). In practice, it is highly desirable to oversize the amount of aeration to allow for unforeseen variations in oxygen consumption rates, hypolimnetic volume increases, temporary equipment shutdowns, and other factors. In light of this fact, a reaeration amount of 12 to 15 pounds of oxygen per minute will be used.

This amount is the quantity needed to maintain the dissolved oxygen concentration of the hypolimnion at the level that existed at the onset of summer stratification assuming 100 percent efficiency. The minimum concentration to support salmonids is 6 mg/l, but higher concentrations are desirable. A small amount of oxygen sag can be tolerated as long as 6 mg/l is maintained at the time of fall turnover. Allowing such a sag would decrease the amount of oxygen needed to be inputted.



From: Stearns and Wheler, 1990

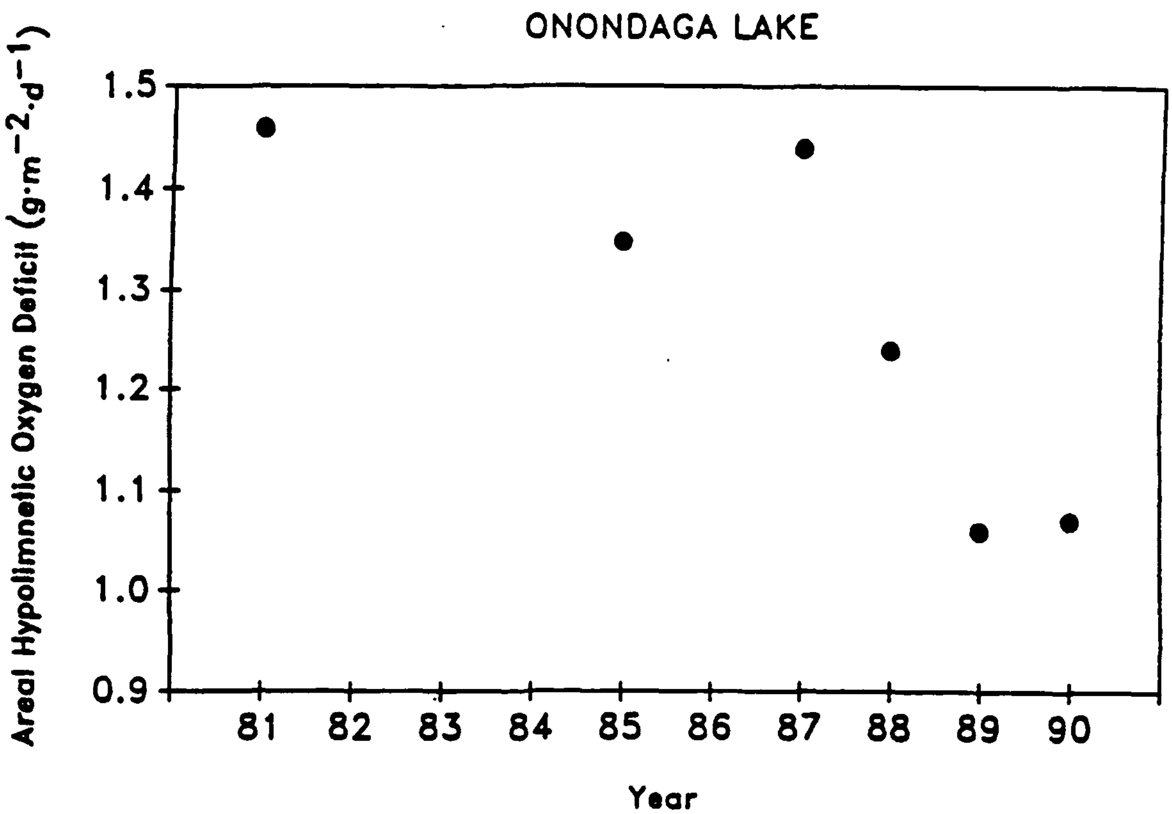
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

DO CONCENTRATION FOR THE EPILIMNION AND HYPOLIMNION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 84

Figure 84



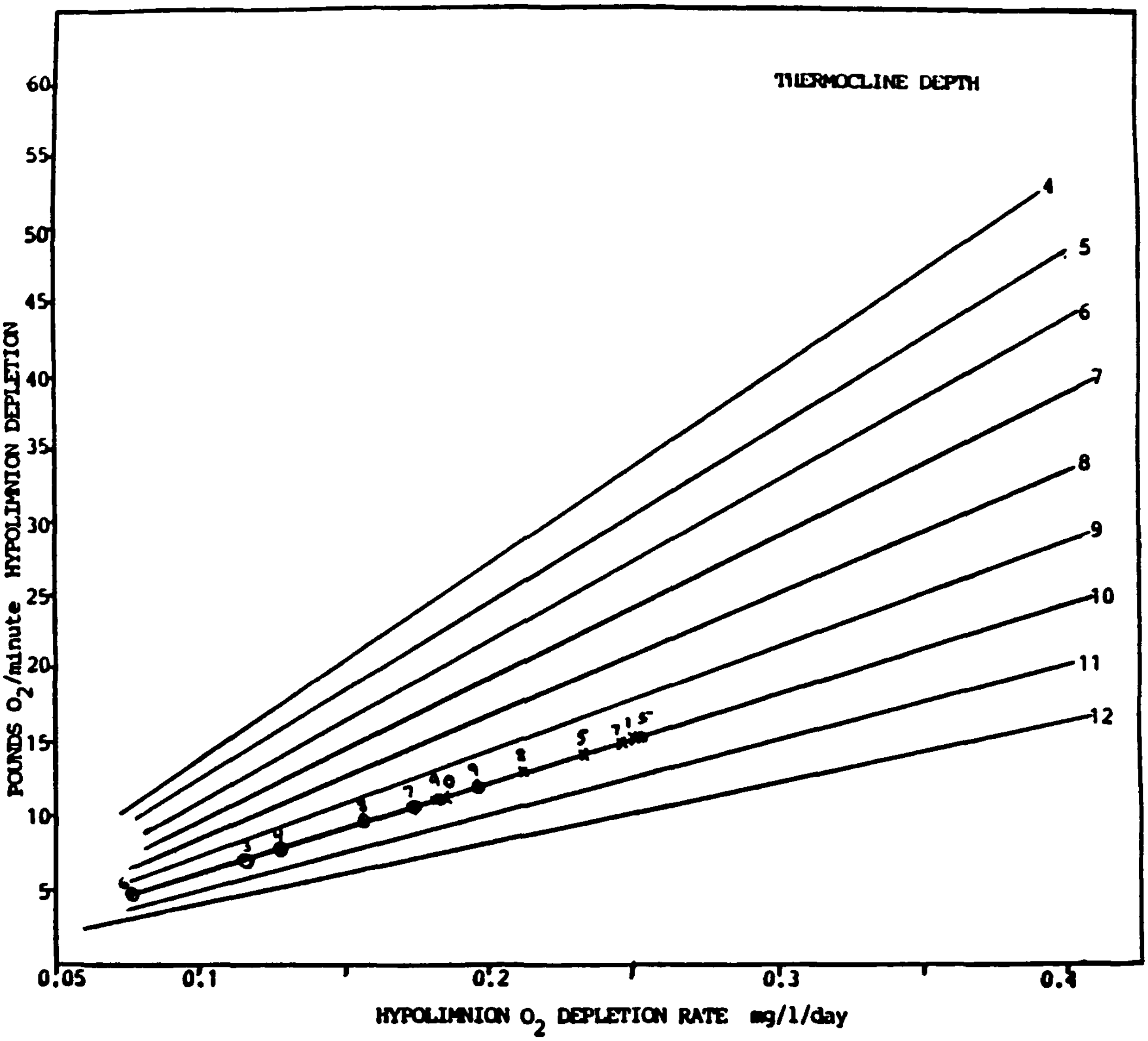
From: UFI, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ONONDAGA LAKE AREAL HYPOLIMNETIC OXYGEN DEFICIT

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 85



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

HYPOLIMNION OXYGEN DEPLETION RATE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 86

Table 38 Hypolimnetic Oxygen Depletion Rates From Selected Eutrophic Lakes and Reservoirs

Lake or Reservoir	Year	Time of Year	Oxygen Depletion (mgO2/1/wk)	Source of Observation or Data for Calculations
El Capitan, CA	1967	S	0.43	Fast (1968)
San Vicente, CA	1973	S	0.25	Unpublished Data (Fast)
Lafayette, CA	1960	S	0.82	Unpublished Data (Fast)
	1961	S	0.62	Unpublished Data (Fast)
	1962	S	0.62	Unpublished Data (Fast)
	1963	S	0.75	Unpublished Data (Fast)
	1964	S	0.35	Unpublished Data (Fast)
	1965	S	0.67	Unpublished Data (Fast)
	1966	S	0.77	Unpublished Data (Fast)
San Pablo, CA	1969	S	0.42	Unpublished Data (Fast)
	1970	S	0.40	Unpublished Data (Fast)
	1971	S	0.38	Unpublished Data (Fast)
	1972	S	0.38	Unpublished Data (Fast)
	1973	S	0.44	Unpublished Data (Fast)
Waccabuc, NY	1973	S	2.1	Fast, (1973a,b)
	1973	S-A	3.0	Fast, (1973a,b)
Ottoville, OH	1973	S	1.32	Overholtz (1975)
	1973	S-A	1.00	Overholtz (1975)
	1973	(1)	1.26	Overholtz (1975)
Mirror, WI	1971-72	W	0.28	Smith, _et al._ (1975)
	1972	S-A	>7.0	Smith, _et al._ (1975)
	1972-73	W-A	>2.5	Smith, _et al._ (1975)
	1973	S	1.3	Smith, _et al._ (1975)
	1973	S-A (2)	2.6	Smith, _et al._ (1975)
Larson, WI	1971-72	W	0.59	Smith, _et al._ (1975)
	1972	W	0.26	Smith, _et al._ (1975)
	1972	F	1.75	Smith, _et al._ (1975)
	1972-73	W	0.08	Smith, _et al._ (1975)
	1973	W	1.54	Smith, _et al._ (1975)
	1973	W-A	0.35	Smith, _et al._ (1975)
	1973	W	0.77	Smith, _et al._ (1975)
	1973	S	2.31	Smith, _et al._ (1975)
	1973	S-A	7.0	Smith, _et al._ (1975)
	1973	F	1.82	Smith, _et al._ (1975)
Onondaga Lake NY	1981	S	1.76	Effler
	1985	S	1.63	Effler
	1987	S	1.74	Effler
	1988	S	1.48	Effler
	1989	S	1.27	Effler
	1990	S	1.28	Effler

S = Spring or Summer rates
F = Fall rates
W = Winter rates (under ice cover)
A = During artificial aeration (hypolimnetic)
(1) Hypolimnion circulated but no oxygen added
(2) July 12 to July 21

From: Tetra Tech Inc, 1977

5.6.1.3.5 Oxygen Sag Example

The theoretical hypolimnetic dissolved oxygen sag is shown in Figure 87. Assuming the oxygen sag curve to be linear, the slope is the oxygen aeration rate minus the oxygen depletion rate. This is equal to the ending minus starting dissolved oxygen concentration divided by the length of the stratification period. The aeration rate is equal to the depletion rate plus the sag rate.

Assuming an oxygen deficit of 0.2 mg/l/day (12.3 lbs/minute) for a hypolimnion starting at 10 meters and a stratification period of 180 days (April thru September) gives a reaeration rate of 0.18 mg/l/day (11.1 lbs/minute) for a starting and ending oxygen concentration of 10 mg/l and 6 mg/l, respectively. This is an oxygen rate savings of 1.2 pounds O_2/minute over full oxygenation.

Changing the ending oxygen concentration to 4 mg/l gives an oxygenation rate of 0.17 mg/l/day (10.5 lbs O_2/minute) or a savings of 0.6 pounds/minute over the above scenario. That is, a sacrifice of a dissolved oxygen concentration of 2 mg/l gives a savings of 0.6 pound O_2/minute in the amount of aeration.

On the other hand, if the hypolimnion is located at 11 meters in the original example instead of at 10 meters, the reaeration rate amounts to 0.18 mg/l or 9.2 pounds O_2/minute as compared to 11.1 pounds/minute for a dissolved oxygen sag to 6 mg/l. The comparison results would be the same if the starting oxygen concentration were different. This savings amounts to 1.9 pounds/minute per 6.8 million cubic meters of hypolimnetic volume.

Higher starting concentration results in lower aeration rates. For example starting at 12 mg/l instead of 10 mg/l gives a rate of 0.17 mg/l/day (10.5 lbs/minute); a savings of 0.6 pound/minute for a starting value change of 2 mg/l.

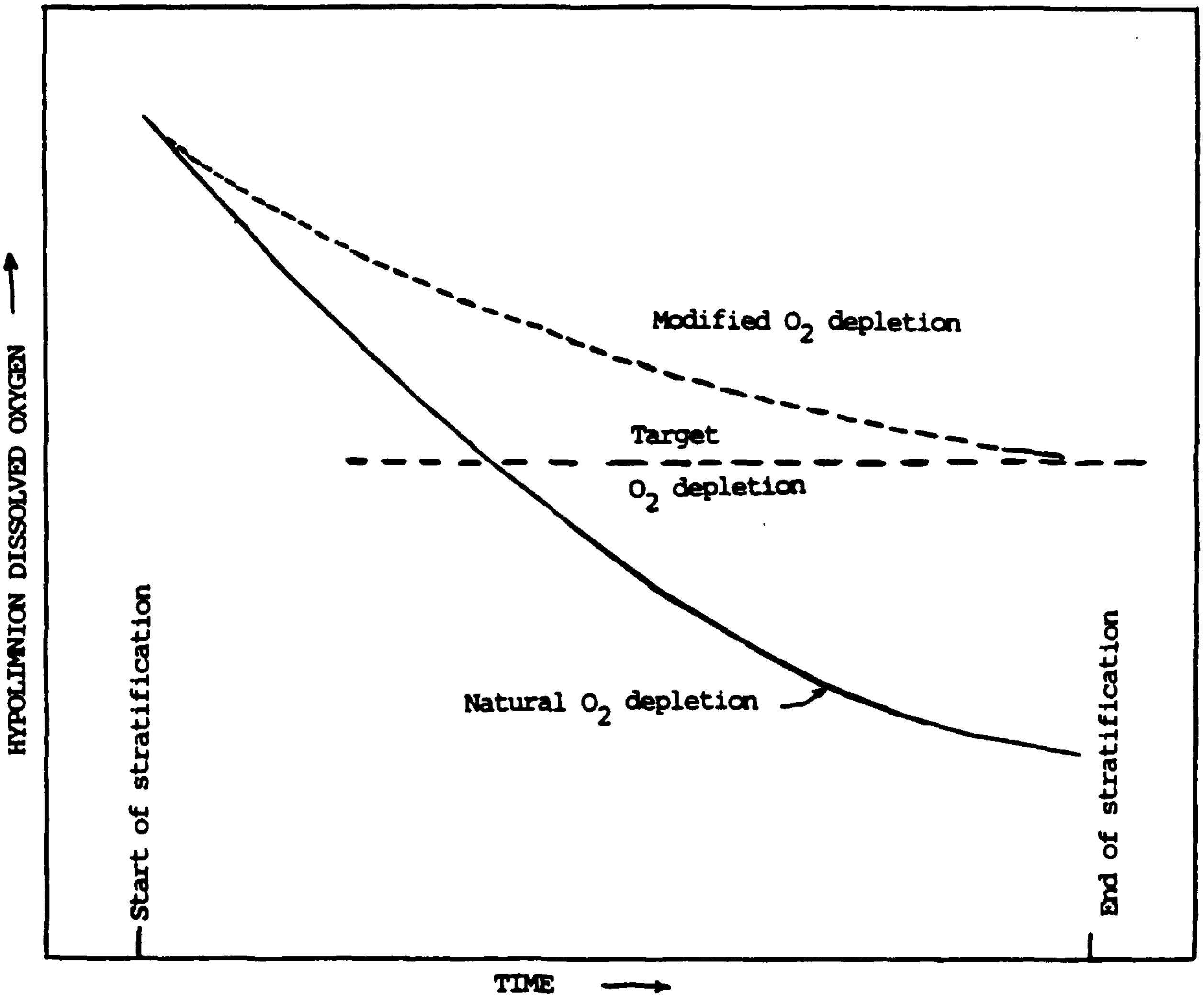
All of the above are used to illustrate the variability in the system and by holding the hypolimnetic volume constant, a savings can be occurred by taking an oxygen sag. This savings is extremely variable and dependent of future unpredictable lake condition. Because of this, the sag shouldn't be used in sizing the oxygen system needed.

5.6.1.3.6 Amount of Air Needed

For an oxygen deficit rate of 0.244 mg/l/day (15 lbs/minute) and a hypolimnetic volume of 40.2×10^6 m^3, the minimum air requirement is calculated as follows:

$$0.244 \text{ mg/l/day} \times 4.02 \times 10^7 m^3 = 9.81\ 10^6 \text{gm/day}$$
$$\text{air @ } 21\%\ O^2 = 8.5 \text{ gm } O^2/ft^3$$
$$\text{air needed} = 9.81 \times 10^6/8.5 = 1{,}154{,}100 ft^3/\text{day}$$
$$= 800 \text{ cubic feet/minute.}$$

Oxygen absorption efficiencies for compressed air have been reported to vary from 5 to 50 percent as shown in Table 35. Even though these efficiencies are for air lift systems, bubbler systems have equally low



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

HYPOLIMNION DISSOLVED OXYGEN VS STRATIFICATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 87

efficiencies. Eight hundred cubic feet/minute are needed as a minimum with 100 percent efficiency. At this efficiency, large amounts of nitrogen would also tend to be absorbed into the water causing supersaturation and aquatic organism problems.

At a 10 percent efficiency, an air flow of 8,000 cubic feet/minute and at a 25 percent efficiency an air flow of 3,200 cubic feet/minute would be required. These are excessively high air compressor rates. Also, full airlift systems expose hypolimnetic water to the warm surface air while hypolimnetic partial airlift systems would have to vent large amounts of air to the atmosphere which might cause stratification unbalances and mixing. A bubbler system with pipes along the bottom of the lake could be used, but once again the large waste of air to the surface could cause hypolimnetic inbalances. Because of the large quantities of air needed with low absorption efficiencies, the shallowness of the hypolimnetic layer, and possible nitrogen supersaturation problems an air system can be ruled out. Pure oxygen systems with higher efficiencies appear more practical.

5.6.1.4 Pure Oxygen Aeration System for Onondaga Lake

At first it seemed the best pure oxygen system to use would have been side-stream pumping. After consulting with Union Carbide's Linde Division's Tarrytown Technical Center, Linde felt that the technology developed in using sparging rafts (Hamilton Harbor - Report on the Water Oxygenation Trial at Hamilton Harbour, 1987 and Amisk Lake - Amisk Lake Oxygen Injection Final Report (Year Two), 1990) could be used effectively for Onondaga Lake. This system would be similar to a bubbler system described earlier. For the amount of oxygen needed, it would be cheaper than the side-stream pumping system. It is felt that an efficiency rate greater than 90 percent can be achieved. Previous studies show that the resulting fine non-dissolved bubbles breaking the thermocline will not mix the waters from the epilimnion and hypolimnion.

In an oxygen injection system, liquid oxygen is stored on shore and is passed through a heat exchanger and turns to a gas (which is under pressure) and, due to pressure caused by changing from liquid to gas, the oxygen is forced along a hose to diffusers placed in the lake bottom.

Liquid oxygen injection is more efficient than traditional aeration systems since the traditional aeration systems deliver air (which consist of only 20% oxygen), thus for the same volume of oxygen to be delivered to the lake, five times as much air has to be pumped into the lake water than if liquid oxygen is used. Also, since liquid oxygen is 100 percent oxygen, diffusion of oxygen out of the bubbles is faster. Also, oxygen injection requires no energy source at the site and there are no moving parts to break down.

5.6.1.4.1 Equipment Description

The necessary equipment can be broken down into the following: land based equipment, the oxygen spargers, and accessory hoses and anchors. Oxygen will be injected into the two basins of the lake. Therefore, two oxygenation units will be required, each delivering 7 to 7.5 pounds of oxygen to the lake waters per minute. The oxygenation system will be used 7 months of the year from April through October. The equipment described will be needed at each site.

Shore setup consists of an oxygen storage tank with the necessary oxygen valves and regulators. This equipment will be located on a concrete pad surrounded by a fence. The tank will be a Driox 13,000 gallon tank holding liquid oxygen. The oxygen will leave the tank by gravity and internal tank pressure feed, and flow through a vaporizer which converts the liquid to a gas. The oxygen then travels through a control system consisting of a pressure regulator, flow meter, and control valve. The oxygen leaves this area through a pipe which is connected to flexible tubing that connects with the spargers.

The oxygen diffusers or spargers consist of rafts about 8 feet long and 5-1/2 feet wide. The outside frame is made out of .4 cm inside diameter PVC pipe. Across the width of the rafts are arranged smaller diffuser tubes having a myriad of 20 micron holes. At the end of the raft where it is hooked to the oxygen line, there is a filter and check valve. Also at this point, there may be a small tube or line that runs to surface. This would be used to fill the system with nitrogen when the system isn't being used with the oxygen. Each raft would be anchored to the lake bottom and leveled. Ideally, the raft would float a foot or two above the lake sediments. Also lines would be attached to the spargers with floats about 10 feet below the lake surface. These lines are used in lifting and lowering the spargers for cleaning.

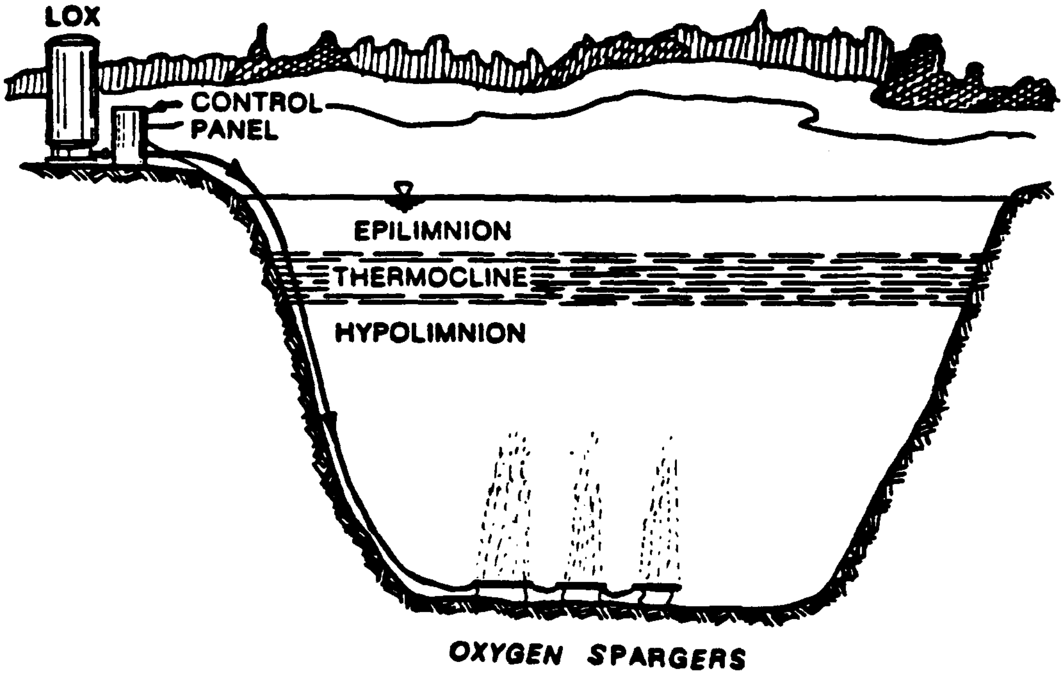
The accessory hose and anchors consist of a long flexible hose running from the land base to the sparger cluster on the lake bottom. This line should be anchored along the lake bottom.

Maintenance procedures include periodically, at least once a year, removing the center diffuser tubes and replacing them with cleaned tubes. The tubes must be acid cleaned for 2-3 days to remove any biological and fine sediment fouling. Since lake oxygenation is planned only during the summer months, it might be practical to remove the spargers at the end of the season, clean and store them for the winter, then clean and install them in the spring. A schematic of the system is shown in Figure 88.

The deepwater sediments of Onondaga Lake have a soft consistency commonly described as "mayonnaise" and may be overlaid by a shallow layer of soft floc type material. During fall and spring overturn there is no indication that these deepwater sediments are disturbed or resuspended. The sparger rafts will be suspended above these sediments such that the rising oxygen bubbles will not disturb these sediments. With similar Linde technologies used at Hamilton Harbor, Amish Lake, and other areas there is no indication of sediment disturbance.

5.6.1.4.2 Preliminary Cost Estimate

Linde stated that for 7.5 pounds of oxygen per minute at each site, 12 sparger rafts would be needed passing 875 pounds of oxygen per day per raft to the lake waters. Each raft would cost approximately $6,500 each. Oxygen would cost approximately $1.00/100 cubic feet with a conversion factor of 12.08 cubic feet per pound. Rental of the oxygen storage tank and controllers would be approximately $2,000/month.



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ONONDAGA LAKE OXYGENATION SYSTEM

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 88

A preliminary capital cost and yearly cost are summarized below in Table 39.

Table 39 Preliminary Capital Cost and Annual Cost @ Each Site

Description	Estimated Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total
First Year Capital Cost						
Spargers	12	Rafts	6,500	78,000	12,000	90,000
Hose & Anchor Accessories		LS		30,000	7,500	37,500
Initial Sparger Installation		LS		24,000	6,000	30,000
Land Based Equipment (Driox Facility)		LS		50,000	12,500	62,500
Real Estate						
lands, easements, & right-of-ways (3 acres)				--	--	--
administration				--	--	--
Total Construction Cost				182,000	38,000	220,000
Planning, Engineering & Design				52,000	--	52,000
Construction Management				23,000	--	23,000
Total Setup Cost				257,000	38,000	295,000
Annual Costs						
Storage Tank Rental	12	Months	2,000	24,000	4,000	28,000
Maintenance		LS		20,000	5,000	25,000
Oxygen	7	Months	38,100	267,000	40,000	307,000
Total				311,000	49,000	360,000
Planning, Engineering, & Design				25,000	--	25,000
Construction Management				9,000	--	9,000
Total Yearly Cost				345,000	49,000	394,000

In summary, two sites are required, therefore, the combined capital and annual costs without and with contingency are $1,204,000 and $1,378,000, respectively. Subsequent annual costs are $690,000 and $788,000. These are the total costs for the two required sites.

5.6.1.4.3 Variable Oxygen Cost

Table 40 below gives the monthly oxygen cost for various minute oxygenation levels per site. These may be used to evaluate other annual costs reflecting reduced oxygenation levels or longer periods of time.

Table 40 Site Monthly Oxygen Cost Per Various Oxygenation Rates

Oxygenation Rate #/Minute	Monthly Cost*
5.0	$ 25,400
5.5	$ 28,000
6.0	$ 30,500
6.5	$ 33,000
7.0	$ 35,600
7.5	$ 38,100

* Does not include contingency.

For example: The required oxygenation period is from the end of the spring mixing (spring turnover) to the end of summer stratification (fall turnover). If this period was extended for an additional month, then the annual cost without contingencies would increase from $345,000 to $421,200 at the 7.5 pound/minute rate. If oxygenation is needed during ice cover, this could also be added (no indication at this time). As another example, if after a couple of years it is found that the required oxygenation rate has dropped to 6.0 pounds of oxygen per minute at each station, then the annual operating cost without contingency would drop by $53,200 at each site, decreasing the total annual costs from $345,000 to $291,800 (excluding contingency).

5.6.2 Chemical Treatment

Chemical treatment of lakes is sometimes used to reduce and remove phosphorus from the lake water and inactivate phosphorus release from lake sediments. This technology has long been used in advanced water and wastewater treatment and has logically and recently been extended to lake rehabilitation. These chemical treatments include the addition of compounds containing metal ions or highly absorbent clays to the water, and letting the material settle to the bottom. Salts of aluminum in the form of aluminum sulfate (alum) are widely used. Current popularity of this method is attributed to its simplicity and the fact that it produces immediate reductions in lake phosphorus concentrations. These phosphorus reductions are only temporary if inflowing nutrients haven't been reduced or eliminated. This is also true regarding phosphorus recycling from the sediments.

Although the importance of phosphorus recycling from anaerobic sediments in delaying the response of lakes to reduced external phosphorus inputs has prompted the use of aluminum sulfate, only recently has the control of sediment phosphorus been specifically identified as a primary treatment objective. The use of aluminum to precipitate phosphorus from the lake water is still often identified as the primary objective of many lake treatments, thus providing little more than short-term relief. If long-term effectiveness is to be realized, treatment methodologies must be optimized for sediment phosphorus control.

Three approaches, each dictated by treatment objectives, have been used for dosage determination. The first involves incremental additions of aluminum compounds to known measures of lake water until a predetermined

phosphorus removal efficiency is attained. This dose, which optimizes treatment for phosphorus removal from the water itself, is then volumetrically scaled for lake application. The second similar method is an extension of procedures employed in waste treatment facilities. With pH controlled, aluminum compound additions are made to constantly mixed lake water samples until optimum phosphorus removal is achieved. The Al/P molar ratio at maximum phosphorus removal and the phosphorus contraction of the lake to be treated are then used to determine lake doses. The controlled laboratory conditions are often quite different from those which occur during lake treatment, and effective lake doses are often underestimated. Also, these experiments are done under controlled pH conditions, a condition hardly achieved in the field. The third method was developed and employed by Kennedy & Cooke (1982) and maximizes the aluminum input to the sediments. This is based on the buffering capacity of the overlying water and emphasizes long-term phosphorus control as a primary treatment objective. Also during application, the aluminum would remove phosphorus from the water column.

If it can be demonstrated that nutrient-rich anaerobic sediment will be a significant source of phosphorus long after external sources are reduced, then aluminum treatments must be targeted against phosphorus exchanges at the sediment water interface.

It is important to maintain the pH between about 6 to 8. Outside this range, aluminum compounds tend to be soluble. As aluminum is added to alkaline lake water, alkalinity and pH decrease. Initially, at low aluminum doses, pH changes are small. If solution pH remains alkaline, the dissolved aluminum concentration will be predictably high. Further aluminum additions decrease pH and alkalinity favoring the formation of insoluble aluminum hydroxide precipitate and dissolved aluminum concentrations decrease. As aluminum additions continue, dissolved aluminum concentrations again increase at low pH, with soluble aluminum predominating below pH 4.

Soluble aluminum is known to be toxic to aquatic biota. The importance of pH change is thus of direct concern in dose determination since, in addition to obvious biota consequences, the pH of treated lake waters will dictate the concentration of potentially hazardous soluble aluminum species and the quality and quantity of aluminum hydroxide produced. Preliminary studies indicate the toxicity level of 50 ug Al/l for salmonid species (Freeman and Everhart (1971), Peterson, et al (1974, 1976)). Kennedy and Cooke (1982) used this as a safe upper limit for post-treatment dissolved aluminum concentrations and the dose was defined as the maximum amount of aluminum which, when added, would ensure aluminum concentrations below this value. Based on solubility, the dissolved aluminum concentration would remain below 50 ug Al/l for the pH range of 5.5 to 9.0. A dose producing a post-treatment pH in this range could be considered environmentally safe with respect to aluminum toxicity.

The formation of large aluminum hydroxide floc which is essential for the deposition of added aluminum would be promoted in this pH range. Rapid removal of floc from the water column is of concern since prolonged suspension of fine aluminum hydroxide particulate further complicates the question of toxicity, and sediment treatment could be adversely impacted by the mixing and dispersion of floc.

The long-term effectiveness of alum treatments will depend on the ability of deposited aluminum hydroxide to retain phosphorus at the sediment/water interface and, thus curtail internal recycling of phosphorus. Secondary, short-term benefits can be realized if water column phosphorus concentrations can be reduced during treatment. Phosphorus removal can occur by coagulation/entrapment of phosphorus containing particulates, precipitation of aluminum phosphate or by sorption of phosphorus on the surfaces of aluminum hydroxide floc. Successful removal of particulates will depend on the quality of floc produced, which in turn is related to pH and aluminum dose. Precipitation and sorption, both influenced by pH and phosphorus concentration are apparently related processes since sorption appears to occur by the formation of aluminum ion phosphate bonds at the surface of aluminum hydroxide floc.

At high phosphorus concentrations, such as those encountered in wastewater facilities, and low pH, aluminum phosphate is the predominant reaction product. However, eutrophic lakes are characteristically alkaline and, despite having biologically high phosphorus concentrations, are relatively low in soluble phosphorus. At low phosphorus concentrations and higher pH, OH^- reacts more readily with aluminum than does phosphate and, thus aluminum hydroxide is the expected product. Therefore, phosphorus removal from the water column will be primarily by entrapment and sorption. Failure to obtain maximum phosphorus removal at the stoichiometric Al/P molar ratio of 1.0, support this suggestion. This is particularly true in the case of lake treatments.

Physical factors influencing phosphate sorption include floc size and settling rate. As floc size increases, specific surface area decreases. Increased floc size also increases settling rates and, thus decreases contact time between the floc and the surrounding lake water. Therefore, phosphorus removal will be highest in the immediate area of the aluminum addition since reductions in pH would be greatest here and floc size would be small. As floc size increases during mixing and settling, phosphorus removal efficiency would be expected to decrease.

Aluminum hydroxide gels deposited on anaerobic lake sediments would be exposed to high interstitial phosphorus concentrations and relatively low pH. Phosphorus removal would continue by further sorption/precipitation and the Al/P molar ratio of deposited gels would decrease with prolonged exposure to high phosphorus concentrations. Laboratory experiments indicate phosphorus removal is pH dependent, and although initially high, is minimal at Al/P molar ratios ranging from 2 to 4. Therefore, effectiveness and longevity will depend on the amount of aluminum deposited relative to sediment phosphorus concentration and the rate at which phosphorus is made available.

Few direct field evaluations of the effectiveness of deposited aluminum hydroxide gels in retaining phosphorus have been reported. Studies indicate reduction rates of 65 to 90 percent. Higher values are observed following treatment.

5.6.2.1 Dosage Determination

One objective of all alum treatments should be the control of phosphorus release from bottom sediments. However, in early treatments, this was often

considered to be secondary to phosphorus removal from the water column. More recently lake treatments have been aimed at the control of phosphorus release from the sediments. Two approaches to dosage determination, both related directly to the treatment objective, have been followed. In the first, dosage is optimized for phosphorus removal from the water column with little attention given to the quantity of floc ultimately deposited on bottom sediments. The dosage would be determined by jar tests in which aluminum salts are added until a desired phosphorus removal is achieved. This laboratory determined dosage was then used directly to calculate the dosage on a lake volume basis. Alternatively, dosage can be expressed as an Al/P molar ratio by dividing the moles of aluminum added by the moles of phosphorus removed, and the dosage to the lake can be calculated based on the phosphorus content of the lake volume to be treated. Usually the dosage of aluminum chosen is small enough that drastic shifts in pH and residual dissolved aluminum (toxicity) do not occur.

The second approach to dosage determination allows maximum application of aluminum to the water column and bottom sediments and, thus emphasizes long-term control of phosphorus recycling. Again laboratory jar tests are employed but dosage is determined by changes in pH and residual dissolved aluminum concentration with phosphorus removal as a secondary consideration (Kennedy, 1978; Cooke, et al., 1978). Initially as aluminum is added, the dissolved aluminum concentrations are high. As the aluminum dosage is increased, pH and alkalinity decrease. In the pH range of 7 to 5.5, aluminum hydroxide floc is formed and the dissolved aluminum concentrations are minimal. As pH and alkalinity continue to decrease with increasing dosage, dissolved aluminum concentrations increase exponentially and then linearly with dosage. A dosage producing an acceptable pH and residual dissolved aluminum concentration is then chosen. Using this method, Kennedy (1978) and Cooke, et al. (1978) defined the maximum dosage as that dosage above which the dissolved aluminum exceeds 0.05 mg Al/l. Titration of lake water samples from several depths of varying alkalinity will establish a linear relationship between residual dissolved aluminum, alkalinity, and the dosage which then can be used for lake-scale applications of alum.

It should be noted that this approach is not suitable for lakes of low alkalinity because the dosage would be too low to exert control of phosphorus bottom sediment release. Another approach would be to add both alum and sodium aluminate at the same time, calculating how much of each is needed to maintain an acceptable pH at which the residual dissolved aluminum will not increase and be below the 0.05 mg Al/l. The use of only sodium aluminate will cause a pH rise and in this case the lake water must be buffered to keep the pH down.

5.6.2.2 Dosage Determination Method

Aluminum solubility is minimal between pH 6 to 8, a range also favorable for removal of inorganic and particulate phosphorus. Therefore, a dosage of aluminum sulfate sufficient to reduce pH to 6.0 is considered an "optimal" dosage. Residual dissolved aluminum which is independent of dosage at this pH, will remain below the toxic level of 0.05 mg Al/l and the amount of aluminum hydroxide applied to the sediments will be maximized. Since this dosage

drastically reduces pH, potential short-term toxic effects in treated areas should be considered. Many of these can be avoided if treatment is confined to the hypolimnion. This phosphorus precipitation/inactivation technique should be used in lakes with moderate retention times. Applications without sufficient diversion of nutrients (METRO) will possibly give only temporary relief to the high phosphorus concentrations. Lakes with low alkalinity could exhibit excessive pH shifts unless the lake is buffered or a mixture of alum and sodium aluminate are used.

The following procedure is taken from "Precipitation and Inactivation of Phosphorus as a Lake Restoration Technique" - Kent State University, February 1981:

(1) Obtain water samples from several areas and depths. The number of samples needed will vary from lake to lake. For lakes exhibiting wide variation in alkalinity, the number of samples should be sufficient to span the entire range of alkalinities.

(2) Determine the total alkalinity of replicate subsamples by titration with 0.02 N H_2SO_4 to a pH 4.5 endpoint.

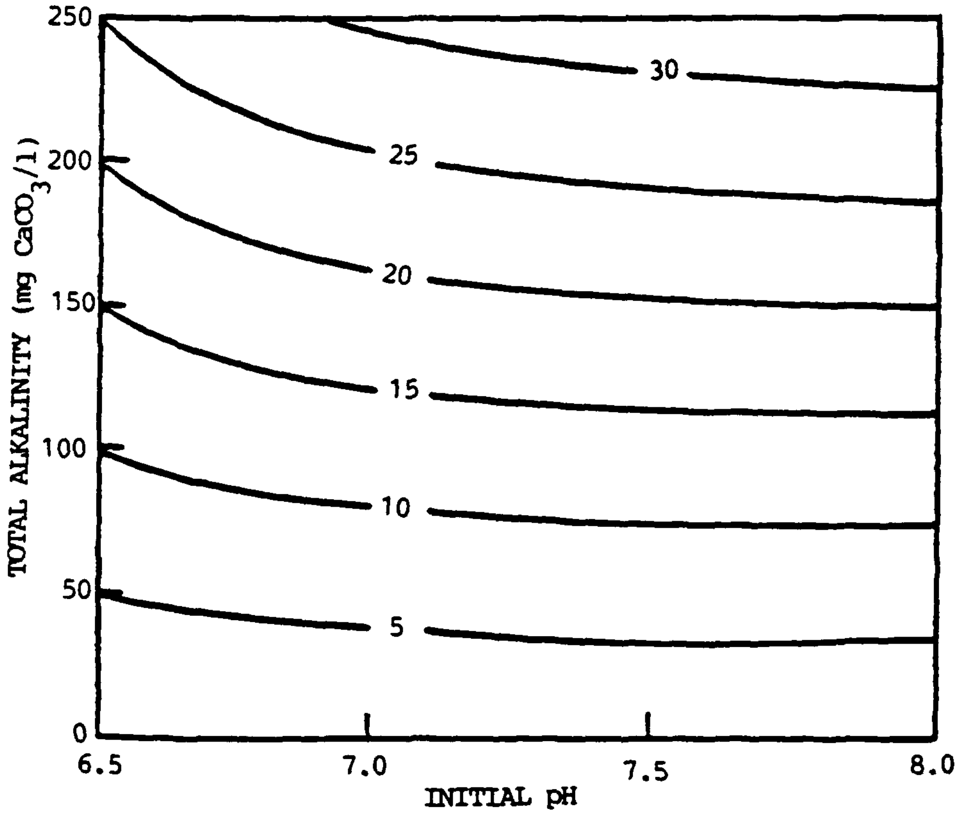
(3) Determine the dose of aluminum sulfate required to reduce the pH of replicate samples to pH 6.0. Initial estimates of this dose, based on pH and alkalinity, can be obtained from Figure 89. Since granular aluminum sulfate dissolved slowly, stock solutions of liquid or pre-dissolved alum should be used. Additions can be made using a burette or graduated pipette. The concentration of stock solutions should be such that the maximum dose to each one liter lake water sample can be reached by an addition of between 5 to 10 ml. Reaction vessels should be stirred using an overhead stirring motor until pH at final dose (i.e., pH 6.0), determined by continuously monitoring with a pH meter, has stabilized (approximately 2 to 5 minutes). Convert the volume of alum stock solution used to a mass per unit volume dose (i.e., mg Al/l) for each sample.

(4) Determine the linear relationship between dose and alkalinity using the information obtained from the above treatments. This can be accomplished by simple regression analysis or by carefully plotting dose vs. alkalinity. This relationship can then be used to determine the dose at any alkalinity within the range tested. The relationship obtained for a particular lake should not be applied to other lakes.

(5) The lake can be divided into convenient treatment areas for ease and accuracy of dose. The total amount of alum to be added to each area is a function of the area's volume and the alkalinities of each stratum (usually each meter). Alkalinity of each one meter stratum is measured. Based upon the relation between dose and alkalinity, the maximum dose for each depth interval is calculated from the maximum dose in mg Al/l to alum/m^3, using a formula weight of 594.19 ($Al_2(SO_4)_3 \cdot 14\ H_2O$) and a conversion factor of 0.02428 to change mg Al/l to pounds (dry) alum m^3, as shown below:

$$\left(\frac{594.19 \text{ mg alum}}{2(26.98) \text{ liter}}\right)\left(\frac{10^3 \text{ liters}}{\text{meters}^3}\right)\left(\frac{2.2046 \times 10^{-6} \text{ pounds}}{\text{mg}}\right) = 0.024228$$

ALUMINUM DOSE (mg Al/l) TO OBTAIN pH 6.0



From: Kennedy & Cooke, 1982

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

DOSE AS A FUNCTION OF pH AND ALKALINITY

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 39

(6) If liquid alum is to be used, further calculations are necessary to express the dose in gallons of alum/m^3. Details are given in Cooke, et al. (1978). Briefly, commercial alum ranges from 8.0 to 8.5 percent Al_2O_3, equivalent to 5.16 to 5.57 pounds dry alum per gallon at 60°F. Alum is shipped at temperatures near 100°F and will, thus have lower density. The percent Al_2O_3 (at 60°F) is supplied by the shipper and this is converted to density, expressed as degree Baume' using Figure 90. A temperature correction is applied against this Baume' number, using Figure 91, to account for the decrease in density. The supplier can estimate the temperature, or it can be checked at the delivery site. Adjusted Baume' is obtained by subtracting the correction factor from the 60°F Baume'. Pounds of alum at shipping temperature are obtained using the adjusted Baume' and Figure 92.

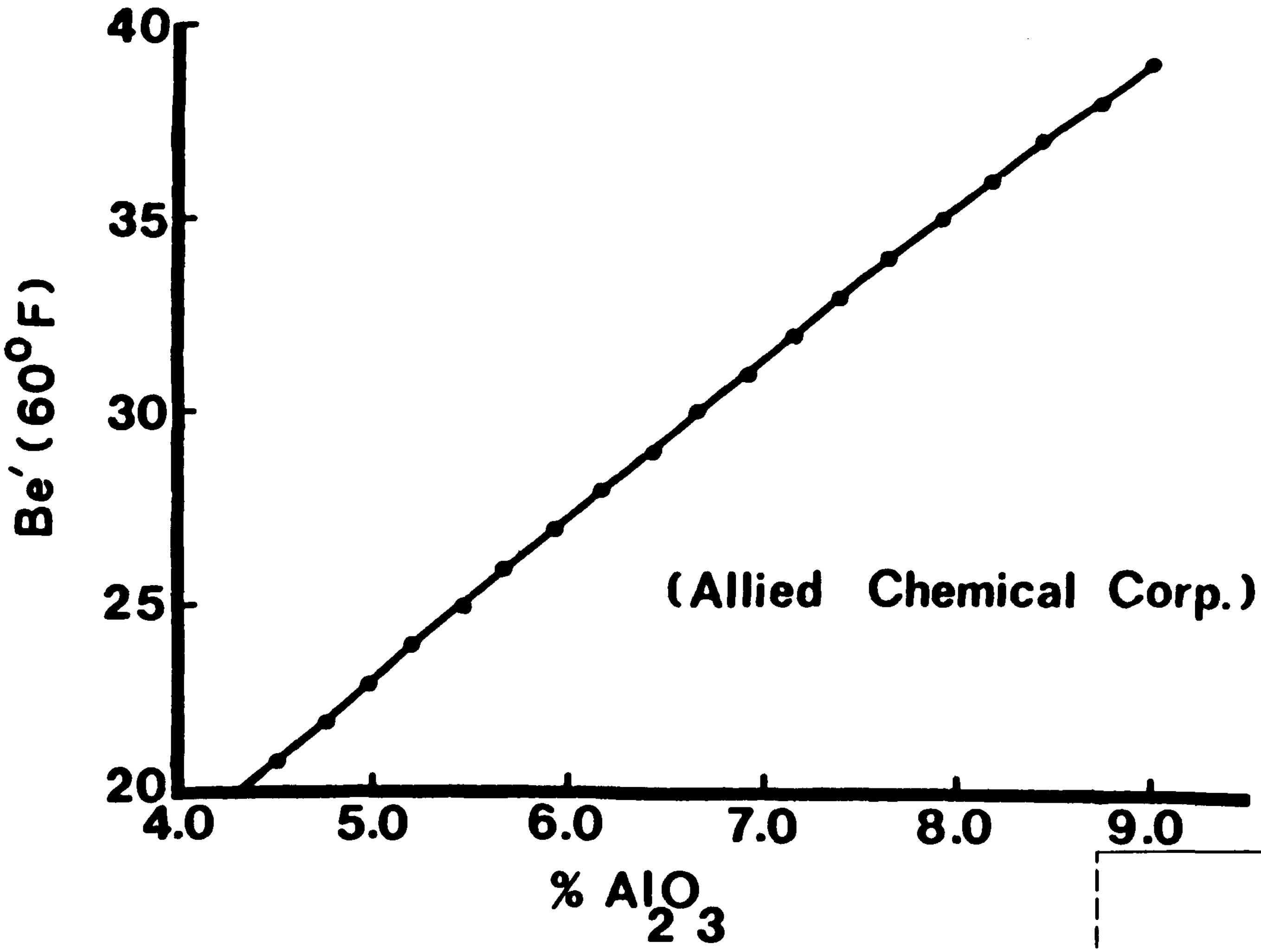
(7) Maximum dose at each depth interval, calculated earlier as pounds of alum (dry)/m^3, is converted to gallons/m^3 by dividing by the value, in pounds per gallon, obtained from Figure 92. Total dose is finally obtained for a treatment area by knowing the volume of each stratum, multiplying the volume by the maximum dose in gallons/m^3, and summing. The sum is applied to the area (e.g., top of the epilimnion or hypolimnion) to be treated.

5.6.2.3 Alum Application Equipment

A simplified schematic of the lake alum application is shown in Figure 93. An on-shore lakeside alum storage tank may be needed depending upon conditions. As the alum is delivered, it can be loaded directly to the treatment vessel. Depending upon the temperature, the alum solution can be quite corrosive. In most cases, the most convenient storage facility is a plastic swimming pool, either on shore or on the treatment vessel. The treatment vessel can take many forms however, it is usually a barge type vessel which is moved by tugs or other boats. Besides the storage tanks or pools, a system of valves and pumps and an application spray boom or manifold is needed. The pumps are used to mix lake water with the alum solution and deliver it to the application spray boom. The valves control the flow rate to provide the right mixture rate. The spray boom consists of a pipe perforated with a row of holes. The boom mechanism is designed to be lowered from the surface to a depth of about 20 feet. The system used for Irondequoit Bay, New York is illustrated in Figure 94. (Monroe County Health Department, 1986)

Figure 94 shows the simplified equipment while Figure 95 (Connor & Smith, 1986) illustrates a more elaborate system. This consists of a modified weed harvester giving greater maneuverability and large payload capacity. For a one time application, the equipment setup shown in Figure 94 would be adequate. For continued application over a period of years and at rates of more than once a year, an equipment setup in Figure 95 might be more appropriate. The precise maneuverability and greater speed of the harvester relative to barge systems gives the harvester better and faster distribution of chemicals to prescribed areas. Application can even be done in reasonably windy conditions. According to Connor & Smith (1986), equipment, labor, and chemical cost comparisons between the modified harvester and barge methods show the harvester to be superior in cost-effectiveness.

An alternative procedure would be to spray the alum on the lake surface using large diameter hoses and a large velocity pump. This could result in a considerable savings in manpower and equipment costs, however, serious



From: Cooke & Kennedy, 1981

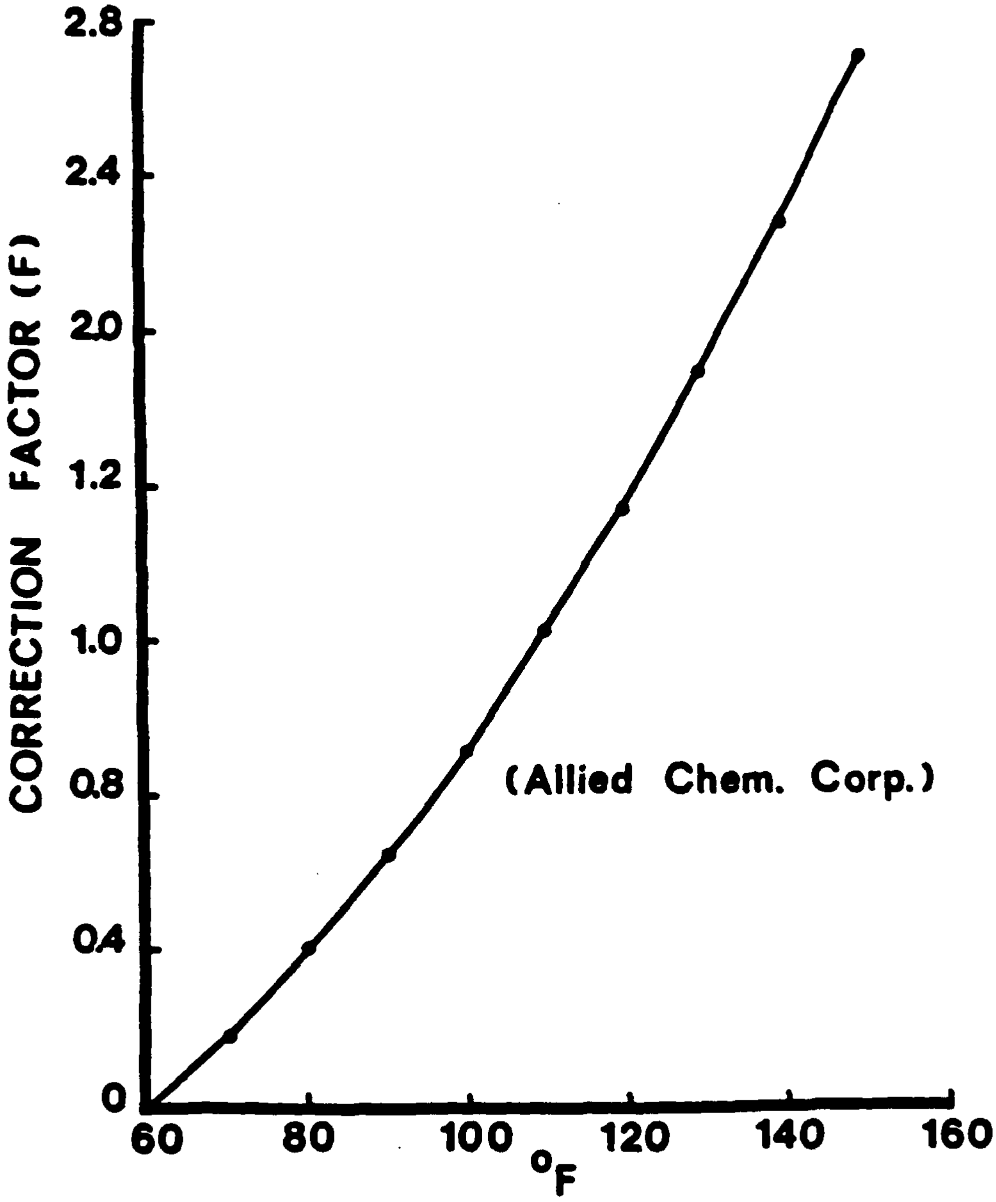
ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISANCE REPORT

RELATIONSHIP OF BAUME AND % Al2O3

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 90

TEMPERATURE CORRECTIONS
(for 32-36° Bé Liquors)



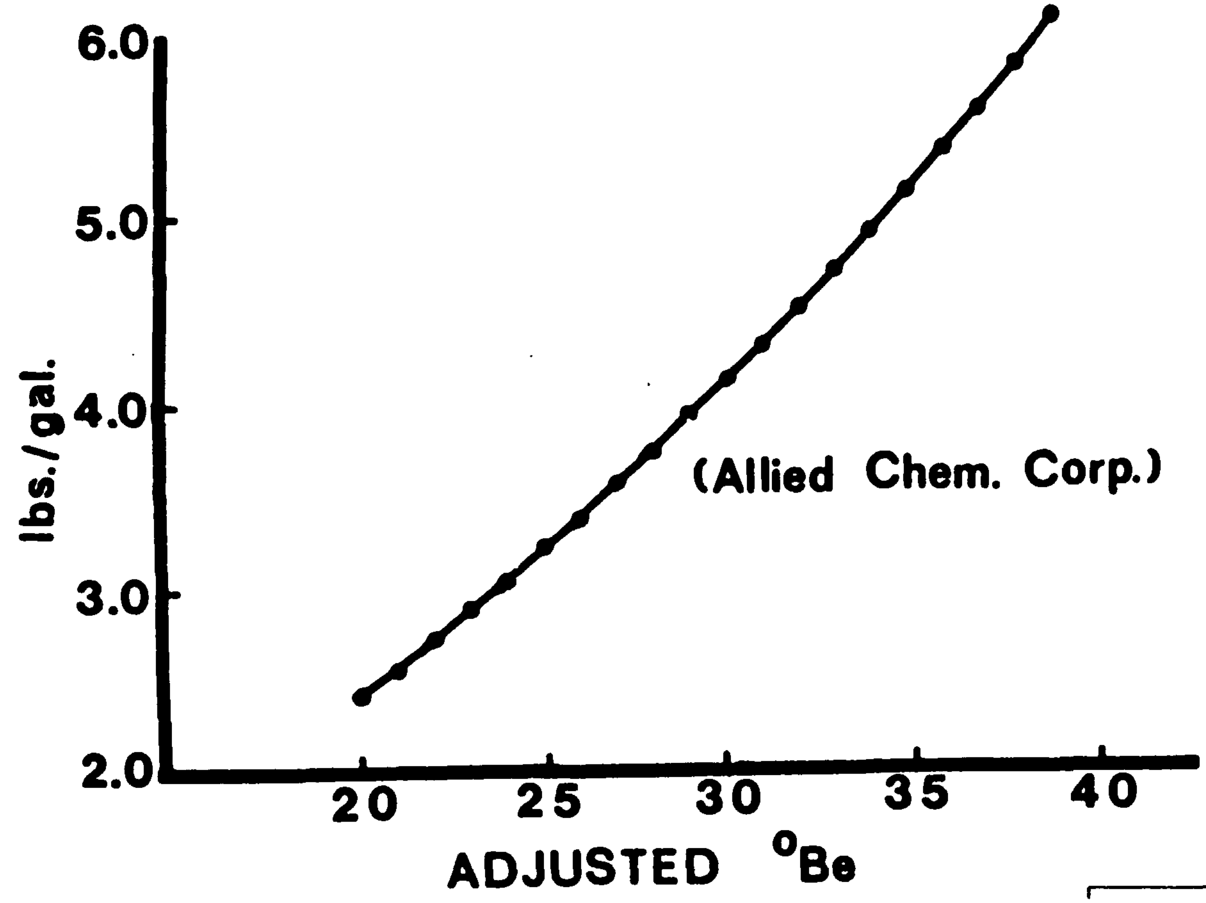
From: Cooke & Kennedy, 1981

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TEMPERATURE CORRECTION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 91



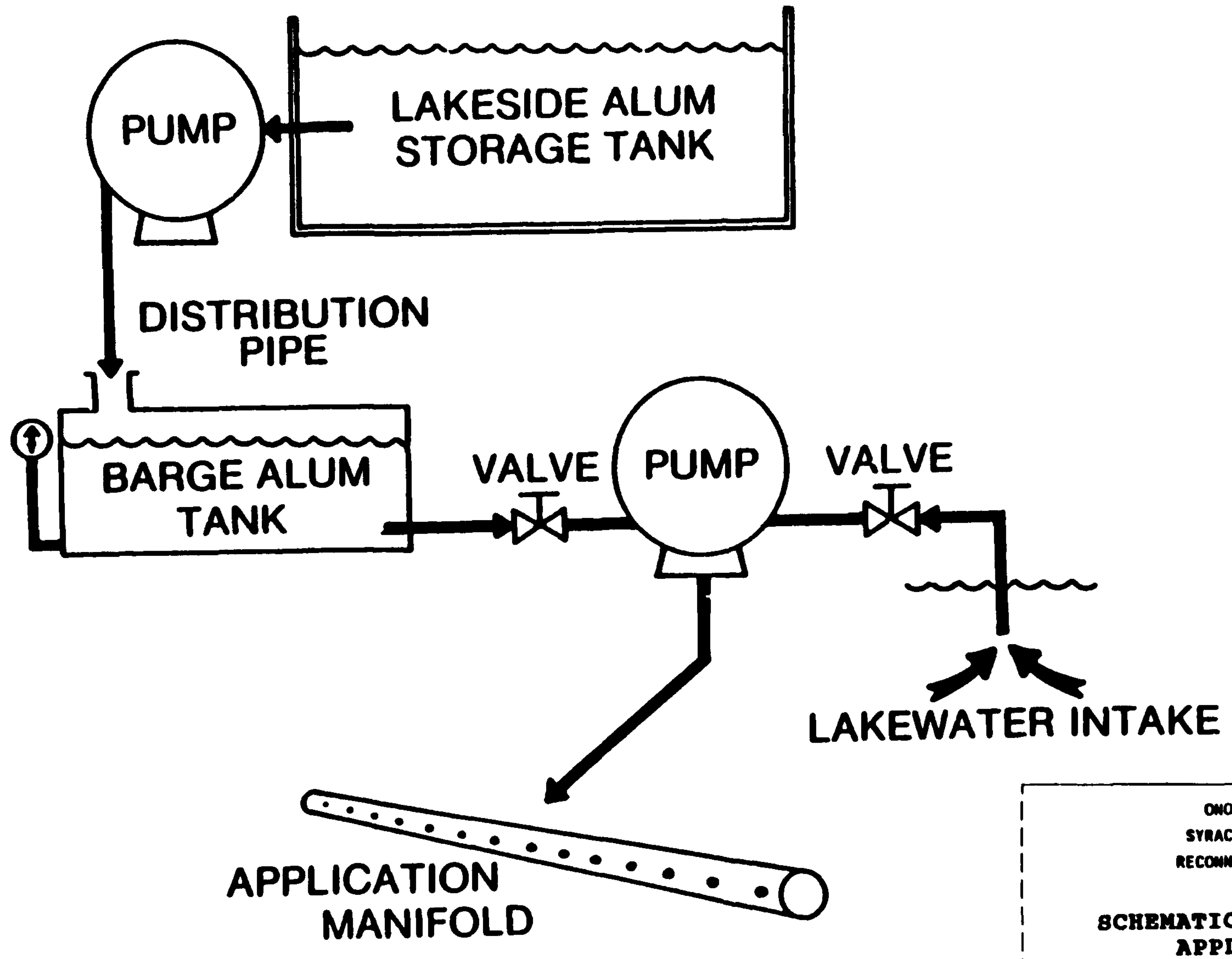
From: Cooke & Kennedy, 1981

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

POUNDS OF ALUM PER GALLON

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 92



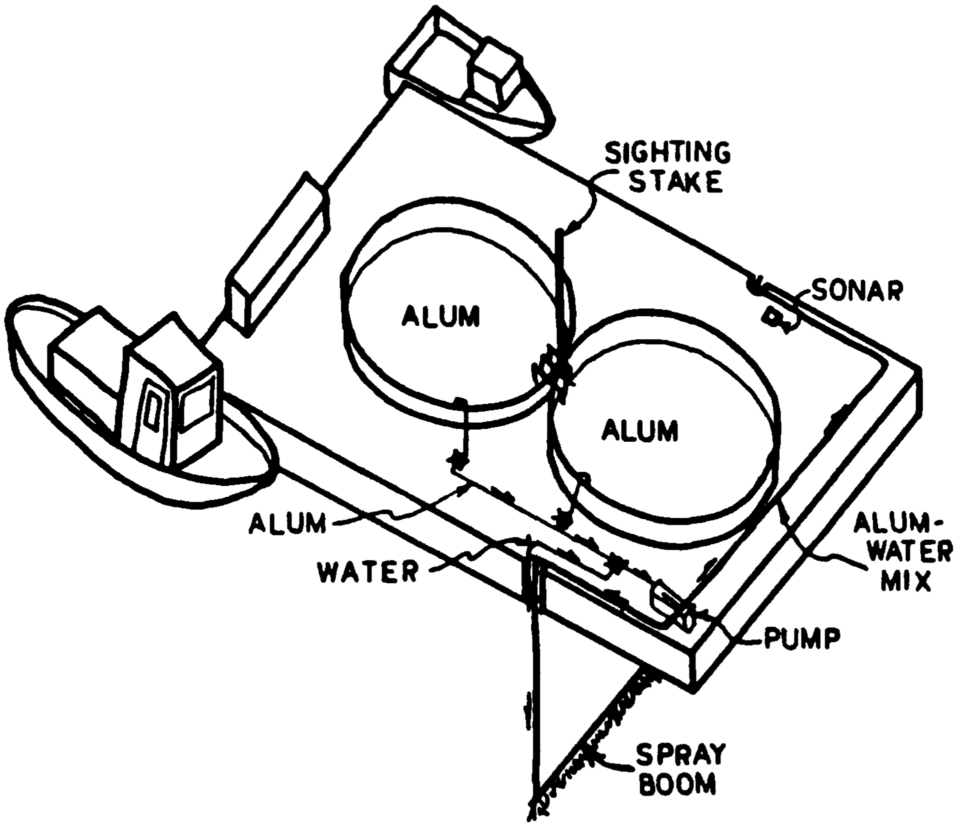
From: Cooke & Kennedy, 1981

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

SCHEMATIC OF LAKE ALUM APPLICATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 93



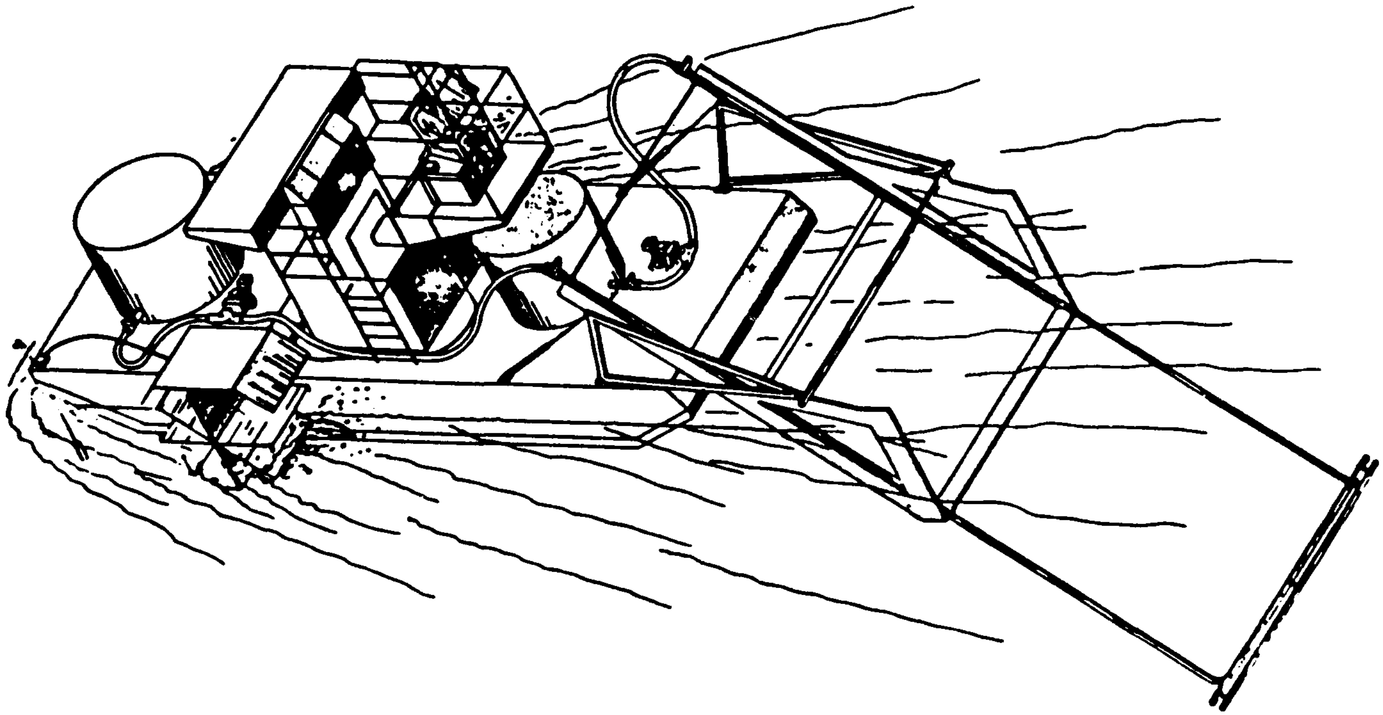
From: Monroe County Health Department, 1986

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ALUM APPLICATION AT IRONDEQUOIT BAY

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 94



From: Connor & Smith, 1986

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ALUM APPLICATION EQUIPMENT

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 95

problems could arise, including localized lethality due to high aluminum or hydrogen ion concentrations from uneven chemical distribution, and poor mixing also leading to locally very heavy amounts of floc.

In theory, an even coverage of the lake surface or hypolimnetic area can be accomplished by using a grid system. Each grid section would receive a different amount of liquid alum depending upon the area's volume, depth, and total alkalinity.

5.6.2.4 1989 Alkalinity Data

The temporal 1989 alkalinity data for Onondaga Lake are shown in Figure 96. These data were derived from Upstate Freshwater Institute sampling program data. Here the lake is divided into the upper and lower 10 meters to reflect differences in the epilimnion and hypolimnion during summer stratification. These data were collected for the south basin of the lake.

5.6.2.5 1989 pH Data

Figure 97 displays the temporal 1989 pH data for Onondaga Lake derived from Upstate Freshwater Institute sampling program data. These data represent the south basin of the lake.

5.6.2.6 Lake Distribution of Alkalinity and pH

Table 41 presents the Onondaga County Monitoring Program data for 1989 as reported by Stearns & Wheler, 1990, for the south and north lake basins. The epilimnion for these data extends from 0 to 7.5 meters in depth and the hypolimnion from 7.5 to the bottom.

Table 41 Lake Distribution of Alkalinity and pH

	Epilimnion		Hypolimnion	
Date	South	North	South	North
3/29/89				
Alkalinity	189	186	188	187
pH	7.7	7.8	7.6	7.6
6/14/89				
Alkalinity	186	189	198	203
pH	7.8	7.9	7.4	7.4
8/23/89				
Alkalinity	132	136	222	216
pH	7.9	7.9	7.4	7.4
10/25/89				
Alkalinity	155	153	153	154
pH	7.5	7.5	7.5	7.5
Yearly Averaged				
Alkalinity	167		193	
pH	7.7		7.4	

5.6.2.7 Time of Alum Application

There has been a great deal of debate as to the optimum time for the application of alum to lake waters to control phosphorus. Mixing is desirable but excessive turbulence could restrict the settling of the floc, possibly restricting the removal of phosphorus from the water and/or the formation of the sediment sponge layer to restrict the sediment release of nutrients. Application probably would not occur on windy days because of application vessel maneuverability problems. Phosphorus precipitations/inactivation techniques would not be effective for lakes with low retention times or if nutrient diversion is insufficient. Low resident time lakes might flush the floc before it had time to settle. Multiple treatments and a combination of surface and hypolimnetic applications could be more effective than a single surface application. If P removal is the objective then early spring is ideal since, as pointed out by Browman et al. (1977) and Eisenreich et al. (1977), most of the P in the water column at this time is inorganic P, a form almost completely removed by the floc. In the summer months a large fraction of total P is in the particulate and dissolved organic fractions, and dissolved organic P is efficiently removed with aluminum. If control of P release is the objective of the treatment then time of application appears not to be as critical since it is the sediments which are the target and not P in the water column.

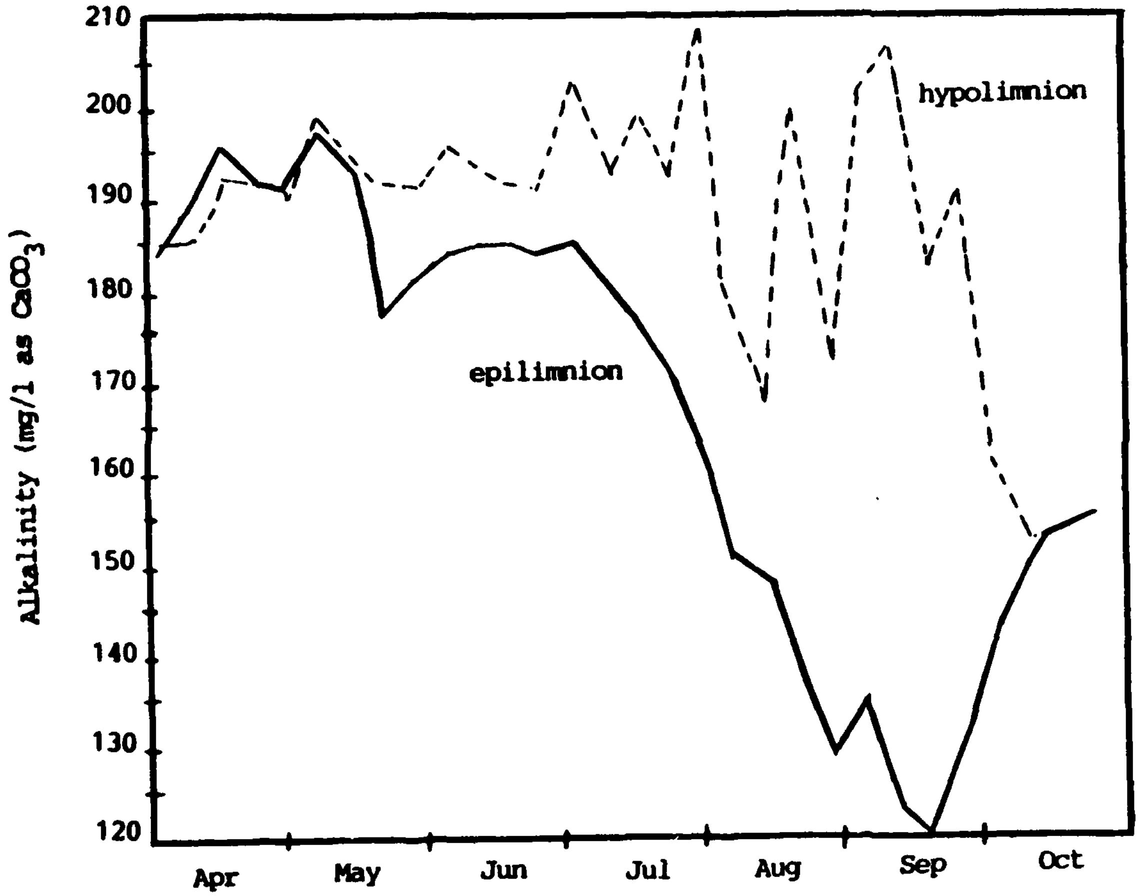
Alum would not be applied to the littoral zone of the lake because this area is wind and wave-swept and unstable. In the deeper areas of the lake, the floc would be incorporated into the sediments such that it would take on the physical properties of the existing sediments. During periods of spring and fall overturn and period of complete mixing the floc would be subjected to resuspension the same amount as regular sediment. Laboratory tests could always be performed to check this. In other lakes where these techniques have been used, there are no indications that the floc layer is severely eroded.

Even though a reduction in the total phosphorus concentration would be realized after treatment, other observable changes might not be seen depending on the lake's productivity. On some lakes improved oxygen conditions, increases in transparency, decreases in chlorophyll content, and shifts in the phytoplankton community from an assemblage of species dominated by blue-greens to a more diverse one with greens and flagellates have been observed.

5.6.2.8 Onondaga Lake Alum Dosage and Total Amount Needed

As an example of dosage determination, consider the following three times of the year on Figures 96 and 97: mid-May, mid-September, and mid-October. These represent the periods at the end of spring turnover, during summer stratification, and the beginning of fall turnover. Jar tests will not be performed and Figure 89 will be used to determine the dosage rates. The area of the lake assumed to be treated is from the surface to the bottom in the area that is 3 meters or greater in depth. The results are summarized below.

May: pH = 8.25 alkalinity = 196 dosage = 27 mg Al/l
volume = 127.72×10^6 m^3



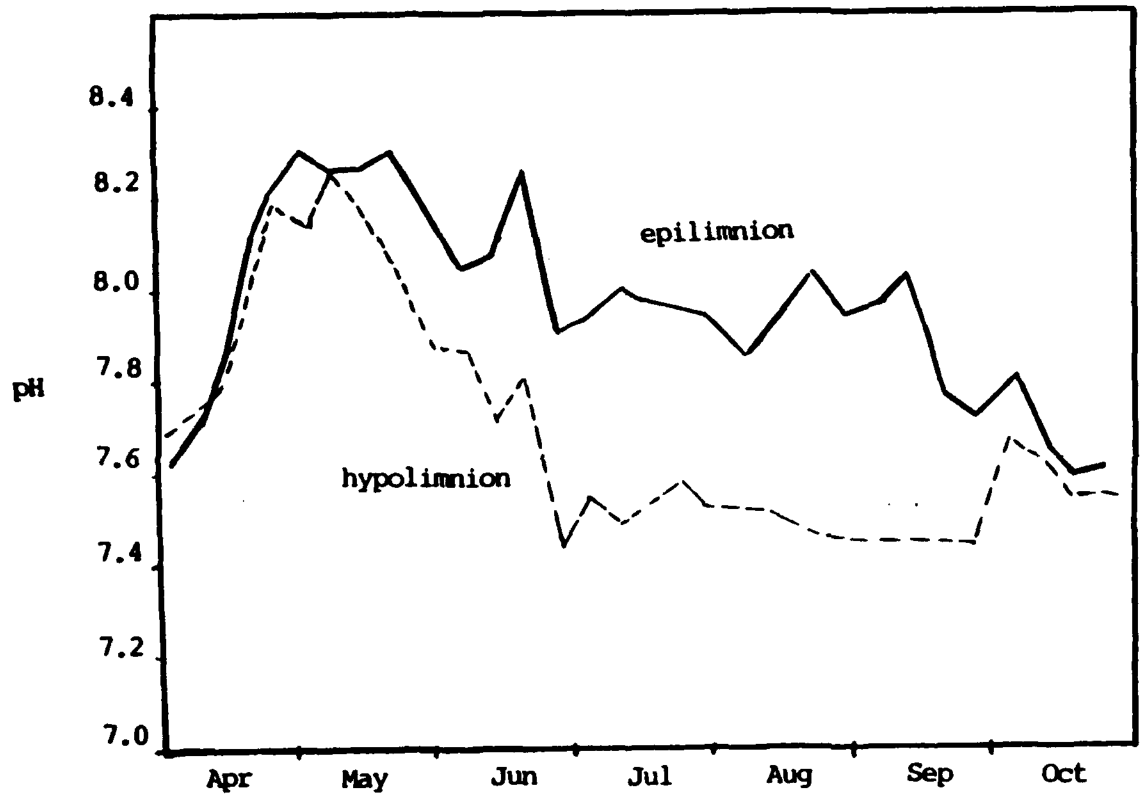
From: UFI, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

1989 ALKALINITY DATA FOR ONONDAGA LAKE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 96



From: UFI, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

1989 pH DATA FOR ONONDAGA LAKE

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 97

Figure 97

September: pH = 7.88 alkalinity = 123 dosage = 16.5 mg Al/1
volume = 87.5 x 10^6 m^3

pH = 7.44 alkalinity = 206 dosage = 26.0 mg Al/1
volume = 40.2 x 10^6 m^3

October: pH = 7.60 alkalinity = 154 dosage = 21 mg Al/1
volume = 127.72 x 10^6 m^3

As an example of the use of Figures 90-92 in conjunction with Step 6 in 5.6.2.2, consider the following. Assuming an Al_2O_3 percentage of 8.0, Figure 90 gives a Be' (60°F) of 35.70. At 100°F on Figure 91, a correction factor of 0.86 is obtained giving a Be' (100°F) of 34.84. This value when applied to Figure 92 gives a pounds/gallon value of about 5.2.

The dosage in terms of gallons/meter^3 are calculated as follows:

May: 27.0 x 0.02428/5.2 = 0.126 gal/m^3

September: 16.5 x 0.02428/5.2 = 0.077 gal/m^3
26.0 x 0.02428/5.2 = 0.121 gal/m^3

October: 21.0 x 0.02428/5.2 = 0.098 gal/m^3

The surface application rate depends on the depth. For example, for the May period, an area with the depth of 5 meters has an application rate of 0.63 gal/m^2 while for the deep portion of the lake with a depth of 19 meter, the surface application rate is 2.39 gal/m^2. In the case of September, if the depth is greater than 3 meters there are two parts to the calculation.

The total amount of alum needed is calculated below.

May: (0.126 gal/m^3)(127.72 x 10^6 m^3) = 16.1 x 10^6 gallons

September: (0.077 gal/m^3)(87.5 x 10^6 m^3) = 6.74 x 10^6 gallons
(0.121 gal/m^3)(40.2 x 10^6 m^3) = 4.87 x 10^6 gallons
11.61 x 10^6 gallons

October: (0.098 gal/m^3)(127.72 x 10^6 m^3) = 12.52 x 10^6 gallons

The commercially supplied alum in the range of 8.0 to 8.5 percent Al_2O_3 equates to about 47 to 50 percent alum. Forty-eight percent alum was used in the treatment of Irondequoit Bay. For this application, alum was commercially supplied at a price of about \$0.50/gal, well below the competitive market price. Water treatment liquid alum at 17 percent costs about \$150/ton or \$0.65-\$0.75/gallon. Using the range of \$0.50 to \$0.75/gallon, as the lower bound, the total chemical cost for one application amounts to:

May:	\$8,050,000 to \$12,075,000
September:	\$5,805,000 to \$ 8,707,500
October:	\$6,260,000 to \$ 9,390,000

Treatment of just the hypolimnion would cost about \$2,435,000 to \$3,652,500 for the alum only.

The treatment objective defines whether the application is made to the surface of the lake or the top of the hypolimnion as well as the time of year the application is made.

Without the elimination of external phosphorus, the input of any chemical treatment would only produce temporary results. Initially the inlake total phosphorous may be reduced by 75 percent. Even though the internal phosphorus sources of sediment release could be temporarily removed (or reduced) the inlake concentration would continue to increase due to the external loading (tributaries and METRO).

Onondaga Lake has a surface area of 1,200 hectares with a volume of $131 \times 10^6\ m^3$ and a maximum depth of 19.5 meters. The largest lake mentioned by Cooke and Kennedy (1981) that was similarly treated has an area of 575 hectares with a volume of 31×10^6 meters and maximum depth of 12 meters. This lake water treated at a rate of 25 gms Al/l at the 7 to 10 meter contour. Only an acre of 121.4 hectares with a small volume was treated. Onondaga Lake has 4.2 times the volume and 1.7 times the surface area.

5.6.2.9 Cost Estimate

Costs for chemical treatment are broken up into two parts, the initial setup and development of application equipment and the actual chemical cost and application. If more than one application is applied, then the setup cost can be distributed. These costs are approximate and are presented in Table 42.

Table 42 Alum Chemical Treatment Cost

Description	Estimated Amount $	Contingency $	Total $
<u>Setup</u> - <u>First Cost</u>			
Application vessel (barge)	20,000	4,000	24,000
Propulsion	30,000	4,000	34,000
Fittings	15,000	3,000	18,000
Total	65,000	11,000	76,000
Construction Management	3,000	--	3,000
Planning, Engineering, & Design	3,000	--	3,000
Total Setup Cost	$71,000	$11,000	$82,000
<u>Each Alum Application</u>			
Maintenance	5,000	1,000	6,000
Chemicals	10,000,000	2,000,000	12,000,000
Sampling & Analysis	20,000	3,000	23,000
Application Cost	30,000	5,000	35,000
Total	10,055,000	2,009,000	12,076,000
Construction Management	2,000	--	2,000
Planning, Engineering, & Design	2,000	--	2,000
Total Each Application	$10,059,000	$2,009,000	$12,080,000

At an estimate of one alum treatment per year, the minimum Chemical annual cost is $12,080,000.

The major constituent of the cost is for the chemicals. Even when treating only the hypolimnion, the application cost would be a minimum of $2,490,000 to $3,728,000 without contingencies.

5.7 Non Point Sources

The Water Quality Act of 1987 focused increased attention and priority on the development and implementation of nonpoint source control programs. Section 319 of the Act requires States to prepare an Assessment Report identifying waterbodies affected by nonpoint source pollution, determining categories of nonpoint sources that are significant problems in the State, and listing State programs available for the control of nonpoint source pollution. States were required to prepare a Management Program which explained how they planned to deal with the source categories causing the major problems.

The New York State Department of Environmental Conservation (NYSDEC) prepared the Assessment Report in 1989 and the Management Program was approved in 1990. The report was based on NYSDEC's existing data base of water control problems.

NYSDEC is working in conjunction with the State Soil and Water Conservation Committee. A two phase approach was initiated to identify the problem waterbodies. The first phase had each Soil and Water Conservation District conduct a survey of nonpoint source pollution in their county. These meetings were held in the first half of 1989. Districts invited agencies, groups, and individuals from within the county to participate in identifying water quality problems. The Districts collected information and presented it to NYSDEC during the next phase of the process.

The second phase consisted of meetings of representatives from the key agencies within each county to discuss the results of the survey. The meetings that were held in 1989, provided the Soil and Water Conservation District personnel and NYSDEC Regional Water and Fisheries staff with an opportunity to discuss the problems in each county. Information regarding the problem was recorded when there was a consensus that a water quality problem existed.

The nonpoint source related water quality problems are verified by the NYSDEC Regional offices, NYSDEC Central Office, or another agency under the guidance of NYSDEC.

The Priority Water Quality Problem list is periodically updated by the NYSDEC Division of Water. Onondaga Lake is included on the list of priority water quality problems. Various tributaries to Onondaga Lake are also on the list. They include, Onondaga Creek, Harbor Brook, Otisco Lake, Ley Creek, and Nine Mile Creek.

6. EVALUATE MEASURES

6.1 Methods of Evaluation

A summary matrix was developed to assess the lake rehabilitation measures with respect to the effects they will have on the following parameters: bacteria, phosphorus, nitrite & nitrate-nitrogen, dissolved oxygen, transparency, ammonia, heavy metals, organics, ionic salts, mercury, and productivity. In addition, the effect the measures will have on the Seneca River was addressed. The matrix is shown in Table 43 and is primarily qualitative, however for some parameters, the results are quantitative.

Bacteria was evaluated with an event bacterial response model that was developed by Upstate Freshwater Institute (UFI). A stochastic model was also developed by UFI to assess phosphorus loading changes to the annual phosphorus budget. The bacteria and phosphorus models were both used to simulate various scenarios and how they respond to the proposed measures. In addition to computing the annual budgets for phosphorus and storm event modeling of bacteria, UFI is developing models to be used with loads for ammonia, nitrate, nitrite, dissolved oxygen, and phosphorus to assess the lakes response over a summer period.

The evaluation of the following lake rehabilitation measures were primarily quantitative: (1) METRO phosphorus and nitrogen removal, (2) METRO discharge to the Seneca River, (3) the regional collection and treatment of CSO's, (4) centralized collection and treatment of CSO's with discharge to Onondaga Lake and the Seneca River, (5) dredging and disposal of contaminated sediment (6) capping of contaminated sediment, (7) remediation of waste beds, (8) removal of mud boils as a source of sediment, (9) in-lake oxygenation, and (10) in-lake chemical treatment. Consultation between Corps personnel and researchers familiar with Onondaga Lake processes provided insight to many of the relevant issues.

As part of the evaluation, cost estimates were developed for some measures. Each available cost estimate is provided in the sections describing the specific measures.

In addition to evaluating the various Onondaga Lake restoration/treatment measures listed in Table 43 using the elements presented in the matrix, a list of restoration goals for the lake was developed for further evaluation. Goals were developed to restore and maintain acceptable swimming areas, improve the habitat for cold water fisheries, and restore the water quality to a level such that minimal treatment will be required for its use as a source of drinking water. Table 44 presents New York State water quality standards for pertinent parameters measured in the lake and/or known to be problematic. The list was narrowed down to those parameters considered most important to achieve the goals for the three classes as presented in Table 45. The effect that the various measures have on the goals is discussed below in each section.

Figure 98 shows an important phenomenon regarding hypereutrophic lakes and the effects of improvements on lake recovery. As the nutrient level increases, the productivity of the lake increases but levels off at some limiting value because the lake becomes biologically nutrient saturated. It is felt that Onondaga Lake lies on the horizontal part of the curve between

TABLE 43 - Evaluation of lake rehabilitation measures on Onondaga Lake and the Seneca River

	BACTERIA	PHOSPHORUS	NITRITE-NITRATE NITROGEN	DO	TRANSPARENCY	AMMONIA
METRO						
PHOSPHORUS REMOVAL	No effect	Up to 50% reduction in external loads	Negligible	Increase in DO	Increase	No effect
NITROGEN & AMMONIA REMOVAL	No effect	No effect	54% reduction in external TKN loads if denitrification is added	Possible increase in DO	No effect	75% reduction in METRO load 67% reduction in external load
DISCHARGE TO SENECA RIVER	No effect	50-80% reduction in external loads	80% reduction in external loads	Increase	Increase	89% reduction in external load
CSO's						
REGIONAL COLLECTION & TREATMENT[1]	Major reduction	1% reduction in external loads	<1% reduction in external loads	<5% removal in external BOD loads	Slight increase	Possible reduction
CENTRALIZED COLLECTION & TREATMENT[1] DISCHARGE TO ONONDAGA LAKE	Major reduction	1% reduction in external loads	<1% reduction in external loads	<5% removal in external BOD loads	Slight increase	Possible reduction
CENTRALIZED COLLECTION & TREATMENT[1] DISCHARGE TO SENECA RIVER	Major reduction	11% reduction in external loads	5% reduction in external loads	10% removal in external BOD loads	Slight increase	Possible reduction
DREDGING & DISPOSAL	No effect	Increase during dredging, reduce sed. release	No effect	Reduce during dredging then increase	Short-term decrease	Short term increases Reduce sediment release
CAPPING	No effect	Reduce sediment release	No effect	Increase	Short-term decrease	Reduce sediment release
WASTE BEDS	No effect	No effect	No effect	No effect	No effect	Decrease
MUD BOILS	Possible Reduction	Negligible	No effect	Possible Reduction	Increase	No effect
IN-LAKE OXYGENATION	No effect	Reduce sediment release	May increase	Increase DO during stratification	No effect	May increase nitrification
IN-LAKE TREATMENT	Negligible	Temporary decrease	Negligible	Possible DO increase	Temporary increase	Negligible

[1] Removal efficiencies based on Moffa & Associates, 1991.

TABLE 43 - continued

	HEAVY METALS	ORGANICS	IONIC	MERCURY	PRODUCTIVITY	SENECA RIVER
METRO						
PHOSPHORUS REMOVAL	Slight decrease	Negligible	Negligible	Negligible	Still hyper-eutrophic	Negligible
NITROGEN & AMMONIA REMOVAL	No effect	Negligible	Negligible	Unknown probably none	May shift algal species to blue-green	Negligible
DISCHARGE TO SENECA RIVER	Decrease	Negligible	No effect	Unknown	Still eutrophic	Increase BOD loads, nitrogen, ammonia, and phosphorus
CSO's						
REGIONAL COLLECTION & TREATMENT [1]	Removed with solids	Negligible	Negligible	Negligible	Negligible	Negligible
CENTRALIZED COLLECTION & TREATMENT [1] DISCHARGE TO ONONDAGA LAKE	Removed with solids	Negligible	Negligible	Negligible	Negligible	Negligible
CENTRALIZED COLLECTION & TREATMENT [1] DISCHARGE TO SENECA RIVER	Removed with solids	Negligible	Negligible	Negligible	Negligible	Increase BOD loads Nitrogen, Ammonia Phosphorus, and Bacteria
DREDGING & DISPOSAL	Remove from sediments	Remove from sediment	No effect	Remove from sediments	Negligible	No effect
CAPPING	Reduce sediment release	Reduce sediment release	No effect	Reduce sediment release	Negligible	No effect
WASTE BEDS	Negligible	Negligible	Decrease	Unknown	No effect	Decrease ionic load
MUD BOILS	No effect	No effect	No effect	No effect	Possible increase	No effect
IN-LAKE OXYGENATION	Decrease Iron and Magnesium	No effect	No effect	Unknown	Possible reduction	No effect
IN LAKE TREATMENT	No effect	No effect	Slight increase	Unknown	Decrease	No effect

[1] Removal efficiencies based on Moffa & Associates, 1991

Table 44. Comparison of Present Conditions With State Water Quality Standards

Suitable For / PARAMETER	1989 Existing Peak / Average []	Swimming Goal	Acceptable Cold Water Fishery Goal	Drinking Water Supply Source Goal
Secci Depth	3.3' 5.2'	4' 4	-	-+
Total Coliform	251	<2400/100ml 4	-	-+
Fecal Coliform	#	200/100ml 4	-	-+
(hypolimnion) Ammonia	6.0 3.6	-	2.06mg/l 1,8 0.27mg/l 5	2.06mg/l 2,8
(hypolimnion) DO	0.0 7.5	-	6mg/l 1	5mg/l 2
Mercury	.2ppb	-	<0.0002mg/l1,*	0.002mg/l 1,3,* 0.005mg/l 2
Nitrite	.72 .182	-	0.02 mg/l 2	10 mg/l 1,2,7
Nitrate	5.0 1.49	-	-	10 mg/l 1,2,3,7
Sodium	255 200	-	-	<20mg/l 1,2,6
(hypolimnion) Calcium	190 159	-	-	-
(hypolimnion) Zinc	.065 .024	-	0.03 mg/l 1	<0.3 mg/l 1,2 5 mg/l 3
(hypolinmion) Cadmium	.013 .003	-	**	<.01mg/l 1,2,3
Copper	.07 .020	-	@	<.2mg/l 1,2 1mg/l 3
Chloride	510 458	-	-	250 mg/l 1,2,3

1. Water Quality Standards and Guidance Values, DEC 9/25/90
2. New York State DEC Codes, Rules and Regulations Section 710.4
3. Chpt I State Sanitary Code, subpart 5-1 Public Water Supplies 1/19/90
4. Chpt I State Sanitary Code, subpart 6-2 Bathing Beaches 3/30/88
5. Defined by UFI
6. From 3 No designated limits <20 mg/l for severely restricted Na diets
   <270 mg/l for moderately restricted Na diets
7. Nitrate & Nitrite in combination
8. Total NH3-N at pH=7.25 & Temp=20, unionized value= 0.0144mg/l

* Guidance value is 0.0002mg/l

\+ Not considered, easily treatable

\# Not specified, too variable

** Exp (0.7852 (ln (ppm hardness)) - 3.49)

@ Exp (0.8545 (ln (ppm hardness)) - 1.465)

Table 45. Onondaga Lake Restoration Goals

Produce Acceptable

Swimming Areas

- Increase transparencies to values greater than state standards.

- Decrease total coliform and fecal coliform to values below state standards.

Produce Acceptable

Cold Water Fishery

- Reduce average total ammonia concentration to level below 0.27 mg/l. Maintain total fixed inorganic nitrogen >0.05 mgN/l to avoid proliferation of nuisance bluegreen algae.

- Increase hypolimnion DO to a minimum of 5 mg/l and daily average of 6 mg/l at any point in the bottom waters and attempt to maintain value close to saturation during summer stratification

- Decrease Hg concentrations in water to a point where accumulation in the aquatic community is minimal.

- Reduce and maintain nitrite-nitrogen concentrations below state standard of 0.02 mg/l.

- Reduce current chloride concentrations.

- Remove the sediment discharge and turbidity of Onondaga Creek thru remedial action on the mud boils.

Produce an Acceptable

Drinking Water Supply with Minimum Treatment

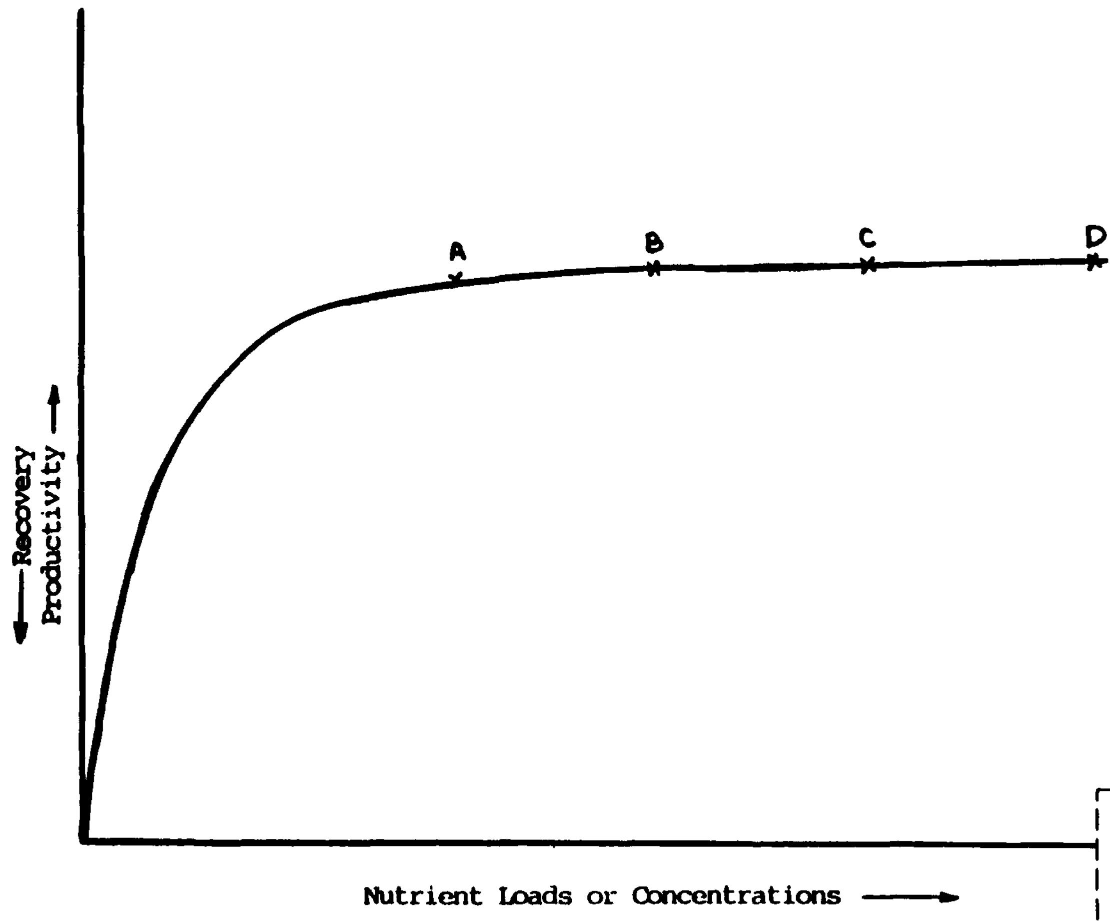
- Reduce and maintain total ammonia concentration to levels below the drinking water standards.

- Maintain nitrite & nitrate-nitrogen concentrations at levels below state drinking water standards.

- Reduce chlorides to a level below 250 mg/l.

- Maintain D.O. in hypolimnion above state standards of 4 mg/l, daily average of 5 mg/l.

points A and D. Whether it lies far to the right (point D) or close to the downward trend (point A) is unknown, however, experts studying the lake feel



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

LAKE PRODUCTIVITY AND RECOVERY

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 98

the loading point is far enough to the right (point C or D) that visible recovery might be hampered. In studying the different alternatives for lake improvement, the shape of this curve must be considered. For example, for the alternatives reducing the nutrient loading of phosphorus and/or nitrogen species from point C to point B, there would be actual reductions in these nutrients but by moving from point C to point B a decrease in productivity may not be realized and hence no noticeable recovery in the water quality will be achieved.

6.1.1 Event Bacteria Model

The main tool used for the evaluation of measures with regards ɔ bacterial loadings to Onondaga Lake was a mathematical model developed by Canale, et al (1990). The computer-based model was designed to be used as a tool in the analysis of the causes of bacterial contamination of the lake, the processes which control such contamination, and strategies for reducing the level of contamination. The model is comprised of sub-models for mass-transport, kinetics and loading. A program of field sampling and field and laboratory experimentation was conducted in support of sub-model development and was subsequently used to provide independent validation of each sub-model. The model was designed to simulate the large scale spatial variation of fecal coliform bacteria along the main, longitudinal axis of Onondaga Lake. Sensitivity analyses have shown that the time course of the lake response to fecal coliform bacteria loads is significantly influenced by environmental conditions, e.g. wind speed, thermocline depth, and light climate. The degree of sensitivity is such that the lake response to a given load can lead to compliance with or violation of water quality standards depending on environmental conditions following the discharge event.

The model was applied to two wet weather events and a dry weather period during the summer of 1987. The duration of each simulation was 7 days. The events simulated include a severe storm in June 1987 (return period of about 7 years) and a smaller, more common storm in July (return period of about 1 year).

6.1.2 Stochastic Total Phosphorus Model

Phosphorus reductions were evaluated by using a stochastic total phosphorus model utilizing the Monte Carlo technique and a deterministic phosphorus model as the analytical framework. This model was developed for Onondaga Lake by Canale and Effler (1989). Measured loads and lake total phosphorus concentrations were used to test the phosphorus model. The model accommodates the influence of both model uncertainty and natural variations in non-point and point external phosphorus loadings to the lake. Statistical distributions necessary to support the Monte Carlo analyses were established through the analysis of historic tributary flow data and an evaluation of the functionality between non-point tributary flows and phosphorus loads. Statistical distributions were also used to describe the external point source (METRO) and variability in the annual net settling.

6.1.3 Total Phosphorus Loadings

Various estimates for nutrient loadings to Onondaga Lake have been made by several researchers using different methods for various reasons. Usually these estimates are made over a short duration (less than a year) or they lack

an adequate number of sampling points or data. The Upstate Freshwater Institute, through support of their Onondaga Lake modeling program, has developed various estimates for summer phosphorus loadings to the lake (Heidtke, 1989). During the summer months of 1987 they conducted an extensive monitoring program on the lake tributaries. Their phosphorus loading estimates for mid-June to mid-August are shown in Table 46. Using the summer loading rates to project an annual load would result in a higher METRO percentage and a lower tributary percentage due to the lack of rainfall during the sampling period. The total 1987 precipitation was 5.42 inches below the 1951-1980 average of 39.11 inches at Hancock Airport in Syracuse, New York. UFI also has worked up a total phosphorus budget for the lake for the summer stratification period mid-May to mid-October as shown in Figure 99. Note that for the summer period METRO contributes approximately 84 percent of the external phosphorus loading, as shown in Table 46. Sediment release contributes approximately 35,000 pounds (16 metric tons) or about 22 percent of the 158,000 pounds (72 metric tons) of the total phosphorus input to the lake waters during the 1987 stratification period of Mid-May to Mid-October as shown in Figure 99.

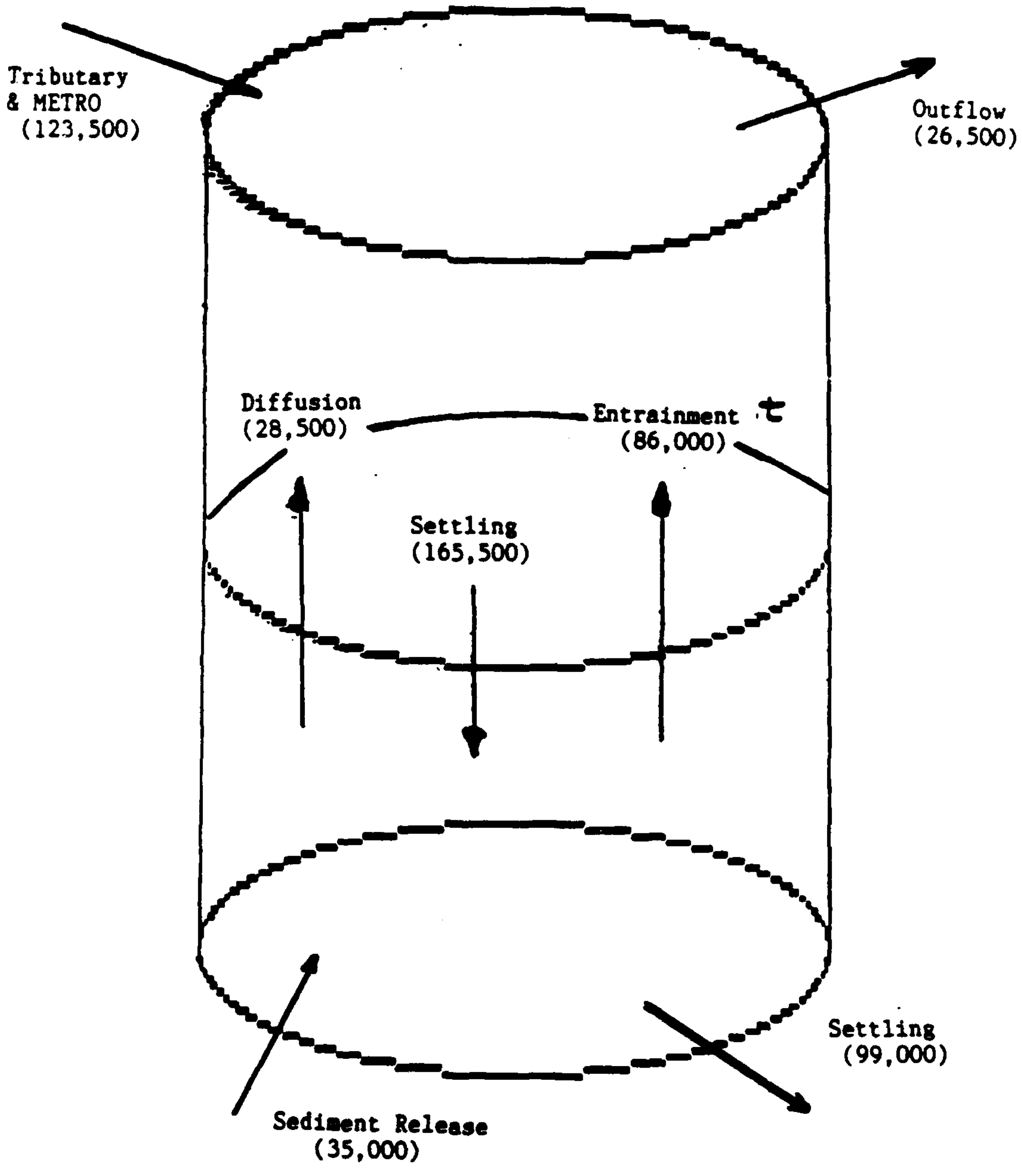
Canale and Effler (1989) developed a relationship between tributary flow and tributary phosphorus load to Onondaga Lake for a 13 year period (1973-1985). The linear relationship (with a correlation coefficient of 0.85) resulted in a tributary phosphorus load of approximately 121,300 lbs/year (55×10^9 mg/year) for the average annual tributary flow from the Onondaga Lake drainage basin of 462 cubic feet per second (413×10^6 m^3/year).

Table 46 - External Total Phosphorus Loads to Onondaga Lake Based on 16 June - 22 August 1987 Sampling*

Source	Load During Period (lb)	Loading Rate (lb/day)	Projected Load (lb/yr)	Contribution (%)
Ley Creek	1504	22.1	8070	2.8
Onondaga Creek	3554	52.3	19080	6.7
METRO Effluent	43767	643.6	234920	82.9
METRO Overflow	695	10.2	3730	1.3
Harbor Brook	196	2.9	1050	0.4
East Flume	362	5.3	1940	0.7
Trib 5A	88	1.3	470	0.2
Nine Mile Creek	2234	32.8	11990	4.2
Sawmill Creek	190	2.8	1020	0.4
Bloody Brook	234	3.4	1260	0.4
Total	52824	776.8	283530	100.0

* From Heidtke (1989)

Moffa, et. al. (1990) presented phosphorus loadings in a paper that discusses water quality impacts from combined sewer overflow and non-point source discharges. The METRO loading was based on an effluent concentration level of 0.75 mg/l over a 365 day period. The combined sewer overflow quantities were based on a total of five storms, representing 23 percent of the total rainfall for 1976. These loadings were then projected to represent the annual rainfall of 36 inches per year, and adjusted for the Best



Total phosphorus budget in pounds developed by UFI for the summer 1987 stratification period of mid-May to mid-October.

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

TOTAL PHOSPHORUS BUDGET

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 99

Management Practices Program. Non-point contributions of phosphorus were based on the bi-weekly monitoring of the tributaries from 1984 to 1986. These calculations resulted in the annual phosphorus loadings as shown on Table 47.

Table 47 - Phosphorus Loadings to Onondaga Lake*

Source	Annual Total Phosphorus Load (lbs)	Percent Contribution
METRO	184,000	67
Non-Point Sources	84,230	31
Combined Sewer Overflows	6,450	2
Total	274,680	100

*From Moffa, et al. (1990)

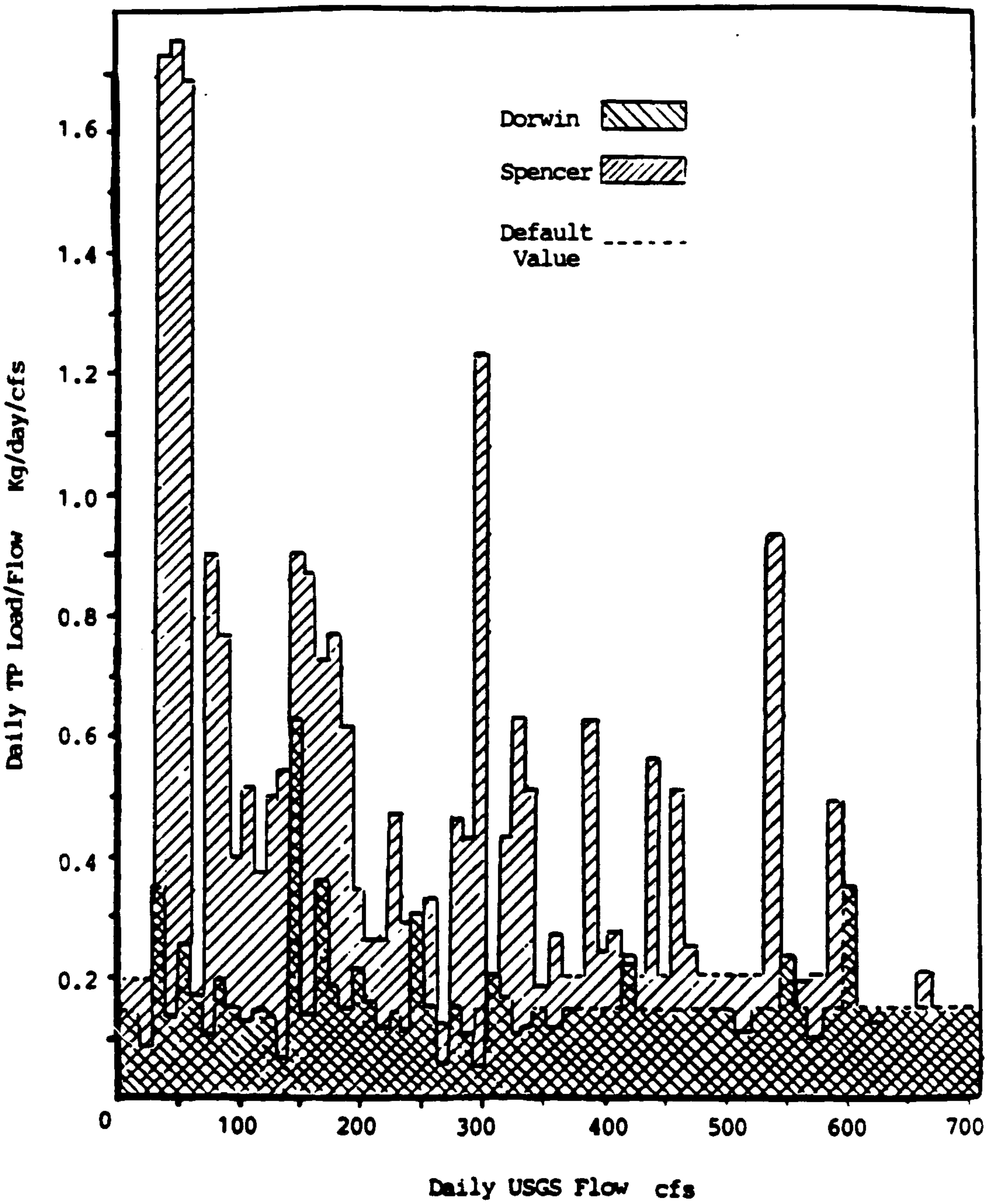
As part of this current study effort, a separate external total phosphorus loading to Onondaga Lake was developed. Loading from the METRO effluent and METRO overflow were taken from Task Report Number 1, Current Metro Syracuse STP Performance Characteristics, Stearns and Wheler, 1990. Tributary loading estimates were based on a sampling program conducted on Onondaga Creek at Dorwin Avenue (upstream station) and Spencer Street (downstream station) by UFI. The calculation procedure is discussed below.

Data consist of instantaneous (hourly) flow and total phosphorus data for 1988 and 1989. These data are not necessarily continuous from day to day. For the days that contained data, a daily total phosphorus load was calculated and related to the corresponding daily USGS flow. Plots of daily loads and flows show no trends or patterns, especially at the Spencer Street site. To define a relationship between flow and load, flow intervals of 10 cfs were used and for each interval the average concentration (loading factor as load/flow) was calculated. These values are extremely erratic as shown plotted in Figure 100. For increasing flows there was no general increase in loading factors trend. Interestingly, at the Spencer Street station, for flows less than 60 cfs the corresponding loading factors were extremely high. Also, these factors were defined by many points. The intervals that didn't have any values were filled in with default values of 0.15 for Dorwin Avenue and 0.20 for Spencer Street up to 600 cfs and 0.15 thereafter. Daily USGS flows and these relationships were used to develop annual loadings for Dorwin Avenue and Spencer Street for 1988 and 1989 as indicated:

Total Phosphorus Loads -lbs/year

Station	1988	1989
Dorwin	12,300	21,700
Spencer	59,950	67,700

Analysis of Onondaga Creek flows for the last 20 years indicates that the total 1989 flow was about average while the total for 1988 was



ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

ONONDAGA CREEK TP LOAD-FLOW RELATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 100

approximately 33 percent below average. Therefore, the 1989 data were used to extrapolate the nonpoint source phosphorus load and CSO loadings to the entire Onondaga watershed.

The 1989 load at Dorwin Avenue was divided by the drainage area at this site to obtain an average rural load per square mile. This load factor was also applied to the additional area downstream of Dorwin Avenue but not within the combined sewered area tributary to Onondaga Creek. The remaining load at Spencer Street was then attributed to the combined sewered area. The resulting numbers are 245 lb/year per square mile for rural area and 5212 lb/year per square mile of combined sewered area. These figures were then applied to all tributaries and combined sewered areas tributary to Harbor Brook and Ley Creek. The resultant total phosphorus loads are shown in Table 48. METRO is the major contributor with Onondaga Creek CSO's the second largest contributor.

Table 48. Corps of Engineers Estimated External Total Phosphorus Loads to Onondaga Lake (Based on 1989 Data)

Source	Load #/year as P	Percent Contribution
Metro Effluent	131120	51.6
Metro Overflow	7260	2.9
Onondaga Ck Rural	24950	9.8
Onondaga Ck CSO	42750	16.9
Harbor Brook Rural	2750	1.1
Harbor Brook CSO	10480	4.1
Ley Creek Rural	6310	2.5
Ley Creek CSO	2140	0.8
East Flume	1930	0.8
Trib 5A	210	0.1
Ninemile Creek	22260	8.8
Sawmill Creek	680	0.3
Bloody Brook	1110	0.4
Total	253,950	100.00

Based on the Corps of Engineers estimated loads and using 35,000 pounds (16 metric tons) for the annual sediment release amount, the total phosphorus load to Onondaga Lake is approximately 289,000 pounds (131 metric tons) per year where the internal load is 12% of the total.

A comparison of the various loadings is presented in Table 49.

Table 49 - Comparison of External Total Phosphorus Loading to Onondaga Lake (Lbs/Year)

	METRO	Tributaries	CSO's	Total
Corps of Engineers	138380 (54%)[1]	60200 (24%)[2]	55370 (22%)[2]	253950
Canale and Effler (1989)	165380 (58%)[3]	121300 (42%)[4]	Inc. w/trib.	286680
Moffa, et al (1990)	184000 (67%)[5]	84230 (31%)[6]	6450 (2%)[6]	274680
Heidtke (1989)	238650 (84%)[7]	44880 (16%)[7]	Inc. w/trib.	283530

1. Based on average 1989 data presented in Task Report No. 1, Stearns & Wheler, July 1990.
2. Based on 1989 sampling data and flows (which were approximately average).
3. Assumes effluent concentration of 1 mg/l.
4. Based on data from 1973 to 1985.
5. Assumes effluent concentration of 0.75 mg/l
6. Based on tributary monitoring from 1984 to 1986.
7. Based on summer 1987 loading rates (a relatively dry year).

The disparity of Onondaga Creek phosphorus loads was addressed in the supplemental work required by NYSDEC as defined in the Workplan for Onondaga Lake Study Management Alternatives. This work included the sampling of four major CSO discharges, three of which were in the Onondaga Creek basin. The primary purpose of the sampling program was to determine whether appreciable shifts in CSO concentrations in several parameters have occurred as a result of the "Best Management Practices Program" implemented by Onondaga County in the early 1980s. This program presented the opportunity to observe Onondaga Creek at the same time.

For this purpose, Region 7 NYSDEC personnel sampled Onondaga Creek during a series of storm events, as coordinated with Moffa & Associates and Onondaga County Department of Drainage and Sanitation.

Projections of CSO flow rates were made through the use of the Stormwater Management Model (SWMM). The resulting CSO discharge volumes were used with average (storm specific) CSO TP concentrations to estimate CSO TP loads.

Four storm events were sampled under this program. If all event loadings are totaled, it was found that 1840 pounds of a total 2,610 pounds of phosphorus originated above Dorwin Avenue (rural). This indicates a 30 percent "urban" total phosphorus source in contrast to the 63 percent urban percentage in the previously described Corps of Engineers analysis.

The projection of annual CSO TP loading based on SWMM modeling and measured concentrations is approximately 15,000 pounds (41 lbs per day).

The above statistics can be compared to the values noted in Table 49 for different phosphorus databases as shown in Table 50. The average daily TP loads that calculated from the Lake Monitoring Report, UFI Replicate Sampling, CSO Facility Plan, and Storms Impact Study databases are all appreciably closer to the results derived from the 1990 sampling effort. The Corps of Engineers loading estimate is higher, as is the NYSDEC estimate, which are based on the same database. Moffa & Associates has disputed the sampling methodology used by NYSDEC for that program (Moffa & Associates, 1990).

Table 50

Comparative Statistics for Onondaga Creek Phosphorus Databases

Database	Monitoring Period	Location	Parameter	Average Conc. (mg/l)	Average Daily TP Load (lbs/Day)	Comments
NYSDEC	4/88-6/89	Spencer St	TP	0.329	197.75	Source: Draft T. Heidtke Memo, 12/18/89
		Dorwin Ave	TP	0.043	7.26	Note: Subsequent release dated 2/2/90
			Urban Area lbs.		190.49	shows TP loads of 189.2 and 35.2 lbs/day
			%		96.3%	Program established to evaluate wet weather loads
UFI, T. Heidtke		Spencer St	TP		52.14	Source: Draft Final Project Report, Onondaga
		Dorwin Ave	TP			Lake Loading Analysis, Total Phosphorus
Lake Monitoring Report (OCDDS)	4/88-6/89	Spencer St	TIP	0.078	72.93	Source: 1/31/90 M&A memorandum,
		Dorwin Ave	TIP	0.079	56.52	Values can be compared to "NYSDEC" database
			Urban Area LBS.		16.41	
			%		22.5%	
Lake Monitoring Report (OCDDS)	1985-1989	Spencer St	TIP	0.092	84.5	Source: 1/31/90 M&A memorandum,
		Dorwin Ave	TIP	0.081	55.99	
			Urban Area LBS.		28.51	Lake Monitoring Report sampling program not
			%		33.7%	specifically structured to evaluate wet weather loads
UFI Replicate Sampling	4/89-9/89	Spencer St	TP	0.087	98.46	Source: "Precision of TP Data from Replicate
		Dorwin Ave	TP	0.067	57.11	Samples From Onondaga Creek," M. Storey
			Urban Area LBS.		41.35	and S. Effler
			%		42.0%	
CSO Facility Plan Annual TP Projections	2/92	Onondaga Creek CSO System	TP		56	Source: "CSO Facility Plan," M&A, 2/91
						Value based upon Long term SWMM simulation and 1990 CSO TP statistics
Storms Impact Study	1976	Spencer St	TIP		90	
		Dorwin Ave	TIP		24	
			Urban Area LBS.		65	

6.1.4 Phosphorus Model Application

The total phosphorus loads used in the stochastic phosphorus model (Canale and Effler, 1989) were the Corps of Engineers estimates (Table 48). These include METRO values of 3.934 x 10^9 ft^3/year (80.6 mgd or 111.4 x 10^6 m^3/year) for flow (1989 Lake Monitoring Program) and 138, 380 pounds/year (360 pounds/day or 59.6 x 10^9 mg/year) for phosphorus loading (Task Report No. 1, 1989). The estimates for the CSO's and tributaries were developed as described in Section 6.1.3.

This model uses a net settling velocity that not only represents settling of phosphorus and algae, but in addition, also represents all other net effects of all phosphorus kinetic and mass transfer processes in the lake. A settling velocity of 34.1 m/year was used for anoxic conditions (Canale and Effler, 1989).

As the phosphorus loading to a lake decreases, the apparent net settling velocities increase, resulting in an increased retention of phosphorus in the sediments. If reductions in phosphorus loading are sufficient to decrease the period of anoxia or eliminate it entirely, phosphorus retention can increase substantially. For example, Nurnberg (1984) found that the average phosphorus retention for anoxic lakes was 33 percent compared to 52 percent for oxic lakes. To represent oxic conditions in Onondaga Lake a net settling velocity of 50 m/year was computed and used.

6.1.5 Phosphorus Loading and Trophic Status

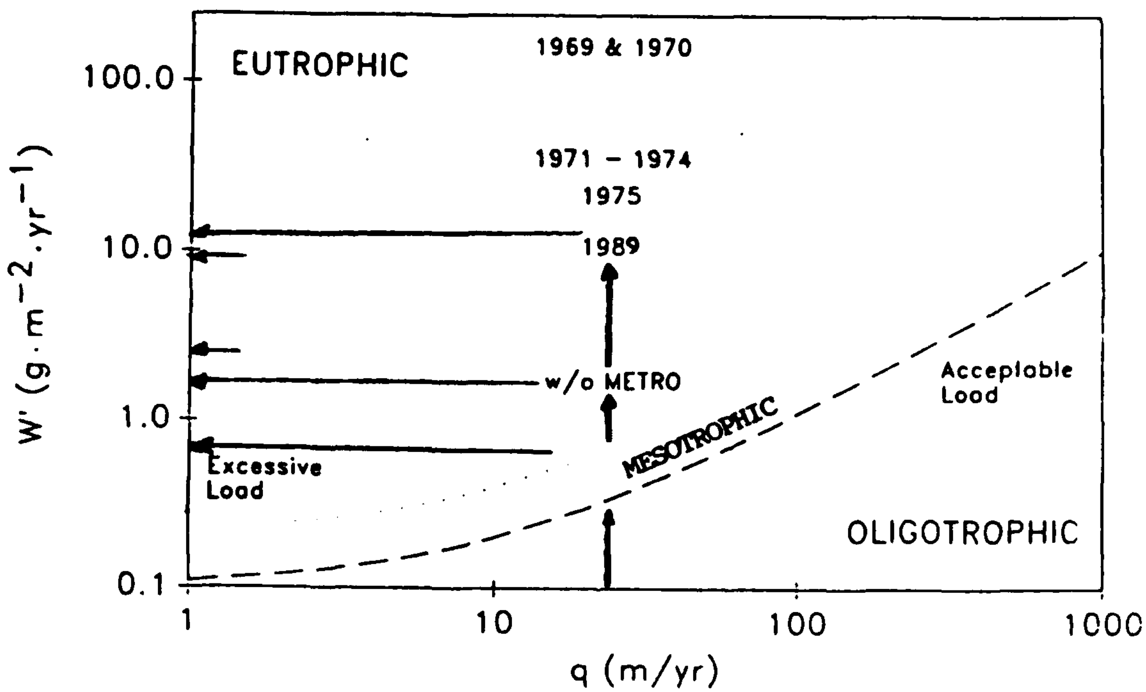
The primary productivity of lakes is often described in terms of trophic levels such as oligotrophic, mesotrophic, eutrophic, and sometimes hypereutrophic, as is the case with Onondaga Lake. Vollenweider (1975) has presented this concept using numbers as a trophic state plot incorporating a unit area total phosphorus loading per year and a unit area flushing rate. This concept was borrowed and expanded by UFI (1990) to present illustrative examples for Onondaga Lake. For a q=24 m/year (based on retention time of 0.5 year and a mean depth of 12 m taken from Murphy (1978), a loading rate greater than 0 7 gm TP/m^2/year (49.4 lbs/day or 22.4 kg/day) for mesotrophic conditions would be considered excessive for this lake as seen from Figure 101. Using Heidtke's (1989) summer loading of 352.3 kg/day and the Corps' loadings (Table 48) of 315.5 kg/day yield areal loading values of approximately 11 and 10 gms P/m^2/year. As shown in Figure 101 these loadings are approximately 16 and 14 times higher than those that result in mesotrophic conditions. Removing METRO's loading from the calculations gives 55.8 and 143 kg/day or loading values of 1.74 and 4.5 gm P/m^2/year. Even without METRO, loadings to the lake are still excessive to produce mesotrophic conditions, 2.5 and 6.5 times too high, respectively.

A total phosphorus loading of 0.34 and 0.68 gms P/m^2/year would be required to bring the lake to oligotrophic and mesotrophic conditions, respectively. The current loading of about 10 to 11 gms P/m^2/year would require a 97 and 94 percent reduction in the total phosphorus loading. METRO contributes approximately 84 percent of the summer load (Heidtke, 1989) and approximately 54 percent of the yearly load (Table 49), thus target reductions cannot be achieved soley through diversion or elimination of METRO effluent.

ONONDAGA LAKE

Phosphorus Loading / Trophic State Plot

(After Vollenweider, 1975)



From: Upstate Freshwater Institute, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

PHOSPHORUS LOADING TROPHIC STATE EVALUATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

With a retention time of 0.25 years a load greater than about 1.0 gm P/m^2/year would take the lake out of the mesotrophic range. A loading rate of 10 gms P/m^2/year is excessive by 10 times and would require a greater than 90 percent reduction.

These calculations reinforce the fact that the lake is highly over loaded with nutrients and METRO removal alone would not restore the lake to mesotrophic conditions.

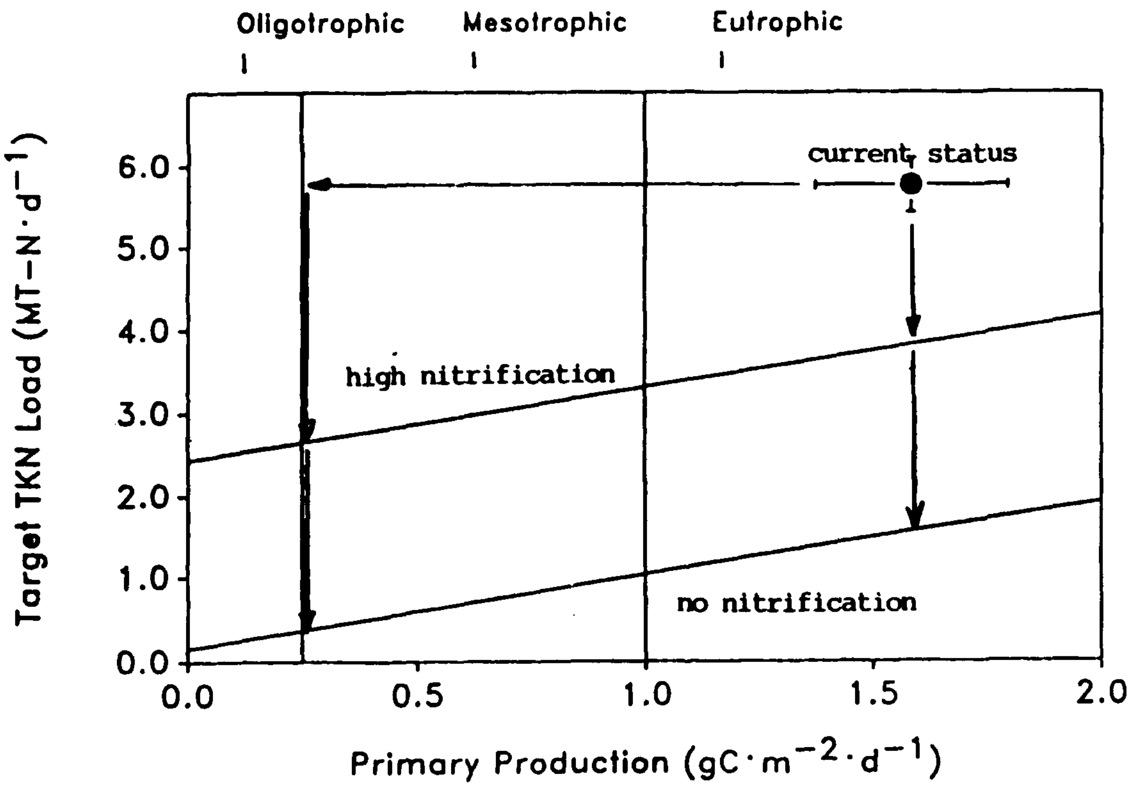
6.1.6 Nitrogen Loading and Trophic Status

METRO has been shown to represent up to 85-90 percent of the external nitrogen loading to the lake on a yearly basis (1989 Onondaga Lake Monitoring Program, Stearns & Wheler, 1990). During the study period of the summer of 1987, it was calculated that METRO contributed 92 percent and Nine Mile Creek 5 percent of the external nitrogen load to the lake (UFI, 1990). For computational purposes it is assumed that all input TKN is ultimately manifested as $T\text{-}NH_3$. Figure 102 shows the nitrogen load reduction required to reach a concentration of $T\text{-}NH_3$ <0.27 mg NH_3-N/l in the epilimnion of Onondaga Lake to avoid ammonia toxicity (Effler et. al., 1990). The reductions are shown for present and future conditions for the cases of high nitrification and no nitrification. Under present conditions removal of 23 to 88 percent of the nitrogen load to the lake is required. To meet future oligotrophic productivity would require from 63 to 100 percent removal of the external nitrogen loadings depending on the amount of nitrification provided by the lake.

6.2 METRO Measures

6.2.1 Phosphorus Removal

The feasible reductions in the METRO phosphorus load and the resulting effects on the lake phosphorus concentration calculated by the stochastic phosphorus model, (Canale and Effler, 1989) are shown in Table 51. It must be noted that as the average effluent concentration is decreased, the standard deviation of the concentration would increase because it would be harder to control the removal process and hold the concentrations close to average. For modeling proposed the standard deviation was not increased, therefore, the actual lake phosphorus concentrations could be higher than those modeled and shown in Table 51 for the lower effluent values. If the goal of 0.07 mg/l total phosphorus at fall turnover is assumed (Canale and Effler, 1989), this shows that eliminating METRO's effluent still does not reduce concentrations enough. These concentrations may not produce a trophic state change in the lake. Additional reductions, perhaps from CSO's would be necessary to achieve the goal.



From: Upstate Freshwater Institute, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

NITROGEN LOAD PRODUCTIVITY EVALUATION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED: APRIL 1991

Figure 102

Figure 102

Table 51. Effects of METRO Phosphorus Removal on Lake Concentrations

Effluent [] mg/l	Load	Reduction in Load #/yr	% Reduction in External Load	Total P [] mg/l
0.54	131120	0	0	0.15
0.50	122540	8600	3	0.15
0.40	98030	33100	13	0.13
0.30	73500	57600	23	0.12
0.20	49000	82000	32	0.10
0.10	24300	106600	42	0.09
0.00	0	131120	52	0.08

Phosphorus removal measures at METRO would have no effect on bacterial concentrations in Onondaga Lake.

The phosphorus removal measures would have negligible effects on nitrogen loading to the lake but could increase lake ammonia concentrations due to reductions in primary productivity (Effler, et. al., 1990). Dissolved oxygen would probably increase due to reduced phytoplankton biomass. Transparency would increase and there would be no effect on ammonia or ammonia toxicity. Heavy metals may be reduced somewhat and the effect on organics, ionic salts and mercury would be negligible. As mentioned previously, the lake would remain in a eutrophic state even with METRO loads totally eliminated, however, a reduction in phytoplankton could result. The effects on the Seneca River would be negligible. Additional phosphorus removal at METRO would address all the goals for Onondaga Lake.

6.2.2 Nitrogen Removal

Nitrogen removal measures at METRO discussed in Section 5.1.3 (denitrification) would not have any effects on the bacteria and phosphorus loadings to the lake. The external TKN loading would be reduced by approximately 54 percent. Section 6.1.6 shows that with the total elimination of the nitrogen source at METRO it may be possible to reach the 0.27 mg NH_3-N/l value to eliminate ammonia toxicity. Also, it might be possible to decrease productivity to reach oligotrophic conditions and maintain ammonia concentrations below the 0.27 mg/l value.

If algal productivity could be decreased, hypolimnetic oxygen and lake transparency could increase over time. Nitrogen removal would have no effects on the heavy metals, organics, ionic salts, and mercury loadings and sediment contaminate concentrations. The effects on the Seneca River are largely unknown at this time and cannot be ascertained until the Seneca River modeling effort has been completed, however, the effects are expected to be negligible.

6.2.3 Ammonia Removal

Ammonia removal through nitrification measures at METRO discussed in Section 5.1.2, will have no effect on bacteria or phosphorus loadings to Onondaga Lake. The external loads of ammonia could be reduced by as much as 67 percent. Dissolved oxygen and transparency could be increased if algal productivity is decreased. There would be no effects on heavy metals, organics, ionic salts, or mercury.

The productivity could decrease due to the decrease of the nitrogen building block. This is usually the case where phosphorus is removed and nitrogen becomes the limiting nutrient. However, if nitrogen becomes too limiting, a problem could develop with bluegreen algae. The effects on the Seneca River would be negligible. Major plant modifications at METRO would be necessary for consistent nitrification to be maintained.

6.2.4 METRO Diversion and Discharge to the Seneca River

This measure will discharge METRO effluent directly into the Seneca River by completely bypassing Onondaga Lake. This would reduce or eliminate many of the problems on the lake, however, it could cause new problems on the Seneca River and eventually Lake Ontario through the introduction of larger phosphorus and nitrogen loads to the river. The effects of this on the Seneca River cannot be ascertained at this time pending the development of a water quality modeling framework by UFI.

Removing METRO effluent from the lake could greatly improve water quality, however, it might not change lake productivity or remove the lake from eutrophic conditions. Generally there would be no change in the bacterial loadings because METRO effluent is chlorinated. The bacterial loadings to the lake result from the unchlorinated CSO discharges.

Because METRO could represent up to 80 to 85 percent of the external phosphorus loading during the summer period (UFI, 1991) and 50 to 55 percent on an annual basis (Corps of Engineers, Table 48), a substantial reduction in lake total phosphorus concentration could be realized. Using the stochastic phosphorus model described earlier with the Corps' developed loadings (Table 48) results in a reduction of in-lake total phosphorus concentration from 0.15 mg/l to 0.08 mg/l or about 50 percent. The Vollenweider plot developed in Section 6.1.5, Figure 101, shows the acceptable loads to the lake are exceeded by about 4.5 times.

METRO supplies about 85-90 percent of Onondaga Lakes' annual nitrogen loading (Stearns & Wheler, 1990, UFI, 1991). The productivity plot developed in Section 6.1.6, Figure 102, shows that with the loadings from METRO removed, the goal of ammonia concentrations less than 0.27 mg/l can be realized especially with in-lake nitrification. However, even with METRO removal the lake could remain in the eutrophic condition.

The changes in the dissolved oxygen concentrations and water transparencies cannot be established at this time because of the complexities involved and the lack of computational and modeling framework.

If METRO discharges heavy metals and organics then these concentrations in the lake would decrease. The sources of these parameters are still uncertain leaving this an area for future study and research. It has been determined that METRO discharges chlorides, however, the amount is minimal compared to the amounts leaching from the waste beds. There would be no significant effect on the chloride level with the diversion of METRO.

At this time, the effect on mercury is unknown. The quantity of mercury that METRO is discharging into the lake is also unknown. With a decrease in nutrient loadings and possible decreases in productivity, there could be an influence on decreasing the mobility of mercury in forming a biological accumulation product. Future research is needed in this area.

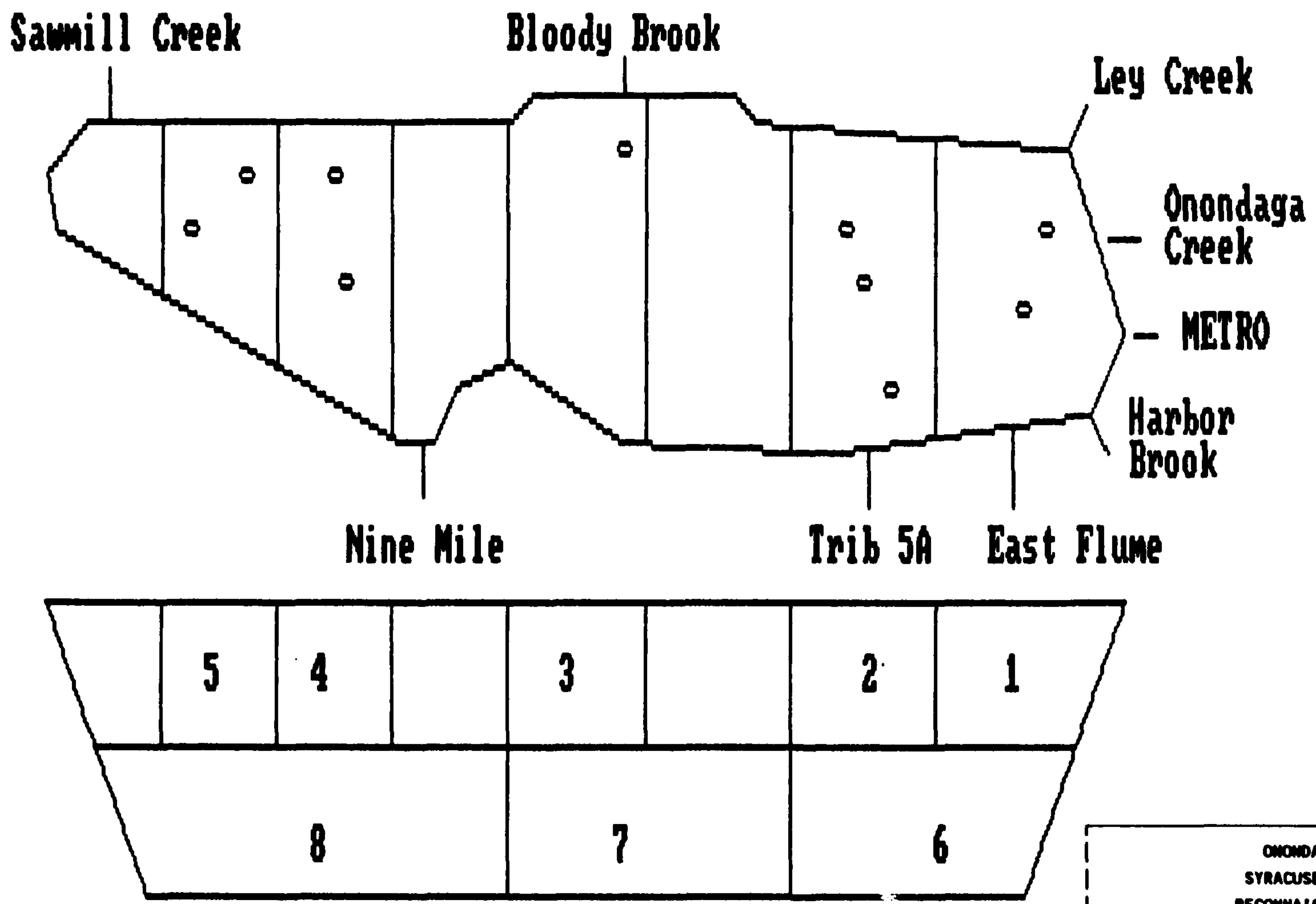
This rehabilitation measure would benefit Onondaga Lake to some extent and the impacts on the Seneca River are unknown at this time. METRO effluent would contribute no bacterial loading to the river but would add nutrients in the form of phosphorus, ammonia, and other nitrogen species. This could produce higher algae productivity in the river during the summer flow periods. A problem could be manifested in the form of ammonia toxicity. These effects are being investigated under the Seneca River modeling effort by UFI.

6.3 Combined Sewer Overflow Treatment Measures

6.3.1 Regional Collection and Treatment

Regional collection and treatment of combined sewer overflows would include disinfection facilities. This evaluation assumes that these facilities would be 95 percent effective in removing the fecal coliform bacteria loads to Onondaga lake from tributary streams. The 95 percent reduction was applied to the loads from Onondaga Creek, Harbor Brook, and Ley Creek and run through the model. In addition, the loads from Bloody Brook were reduced by 95 percent due to the construction of the Liverpool Pump Station. The lakestations where resulting fecal coliform bacteria concentrations are calculated are shown in Figure 103. Tables 52 and 53 show the number of hours that the fecal coliform bacteria concentration is above the standard of 200 colonies per 100 ml for each storm event and the peak concentrations under the measured conditions.

For both storms, measured environmental conditions consist of a 6 meter thermocline depth, average wind speeds of about 2.7 meters/second, and light conditions and water attenuation values of 166 $cal \cdot cm^{-2} \cdot day^{-1}$ and $1.65 m^{-1}$ for the June storm and 217 $cal \cdot cm^{-2} \cdot day^{-1}$ and $0.6 m^{-1}$ for the July storm. For modified conditions, 8 meters is a deep thermocline and 4 meters is a shallow thermocline, a strong wind is 3 times the measured speed and mild wind is one fifth of measured wind speeds, sunny/clear conditions represent values of 300 $cal \cdot cm^{-2} \cdot day^{-1}$ and $0.5 m^{-1}$ while cloudy/turbid conditions are 12 $cal \cdot cm^{-2} \cdot day^{-1}$ and $2 m^{-1}$.



From: Canale, et al, 1990

ONONDAGA LAKE
SYRACUSE, NEW YORK
RECONNAISSANCE REPORT

FECAL COLIFORM MONITORING STATIONS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REPORT DATED:APRIL 1991

Figure 103

Figure 103

Table 52 - June 1987 Storm Modeling Results
(hours above 200 colonies and peak condition)

	Lake Stations (Figure 105)							
	1	2	3	4	5	6	7	8
Measured Conditions and Loads	65 / 1880	62 / 1320	55 / 827	51 / 547	48 / 495	53 / 415	0	0
Measured Conditions Improved Loads	0	0	18 / 315	25 / 411	24 / 334	0	0	0
Conditions: Strong winds, Deep Thermocline, Sunny/clear, Measured Loads	38 / 740	36 / 589	33 / 522	30 / 468	29 / 443	0	0	0
Conditions: Strong winds, Deep Thermocline, Sunny/clear, Improved Loads	0	0	2 / 209	7 / 255	6 / 240	0	0	0
Conditions: Mild winds, Shallow Thermocline, Cloudy/turbid, Measured Loads	145 / 11900	137 / 3290	74 / 777	49 / 557	34 / 308	132 / 2270	0	0
Conditions: Mild winds, Shallow Thermocline, Cloudy/turbid, Improved Loads	7 / 208	0	24 / 324	39 / 547	28 / 297	0	0	0
Conditions: Strong winds, Deep Thermocline, Cloudy/turbid, Measured Loads	58 / 785	56 / 656	52 / 600	49 / 546	49 / 534	15 / 209	0	0
Conditions: Strong winds, Deep Thermocline, Cloudy/turbid, Improved Loads	0	0	11 / 232	14 / 280	14 / 270	0	0	0
Conditions: Mild winds, Shallow Thermocline, Sunny/clear, Measured Loads	58 / 2670	34 / 578	13 / 258	18 / 388	0	47 / 444	0	0
Conditions: Mild winds, Shallow Thermocline, Sunny/clear, Improved Loads	0	0	7 / 222	18 / 388	0	0	0	0

Table 53 - July 1987 Storm Modeling Results
(Hours above 200 colonies and peak concentrations)

	Lake Stations (Figure 105)							
	1	2	3	4	5	6	7	8
Measured Conditions and Loads	52 1310	47 779	39 439	27 257	21 229	29 247	0	0
Measured Conditions Improved Loads	0	0	0	0	0	0	0	0
Conditions Strong winds Deep Thermocline Sunny/clear Measured Loads	32 578	29 452	25 317	20 266	18 260	0	0	0
Conditions Strong winds Deep Thermocline Sunny/clear Improved Loads	0	0	0	0	0	0	0	0
Conditions Mild winds Shallow Thermocline Cloudy/turbid Measured Loads	83 2590	61 787	0	0	0	66 474	0	0
Conditions Mild winds Shallow Thermocline Cloudy/turbid Improved Loads	6 252	0	0	0	0	0	0	0
Conditions Strong winds Deep Thermocline Cloudy/turbid Measured Loads	48 597	45 470	42 357	37 328	38 325	0	0	0
Conditions Strong winds Deep Thermocline Cloudy/turbid Improved Loads	0	0	0	0	0	0	0	0
Conditions Mild winds Shallow Thermocline Sunny/clear Measured Loads	56 2360	33 554	0	0	0	44 346	0	0
Conditions Mild winds Shallow Thermocline Sunny/clear Improved Loads	0	0	0	0	0	0	0	0

During the June 1987 storm, if the regional facilities were in place, the state standard is predicted to be exceeded for 25 hours at station 4 as compared to 51 hours without treatment. Violations would be totally eliminated at several other stations. Improvements would have eliminated all violations during the smaller July storm.

It is also important to determine how variability in environmental conditions can impact the likelihood of a water quality violation at the proposed recreation sites. Four sets of environmental conditions were simulated. These would cover the best and worst conditions at each end of the lake. The scenarios would be as follows:

South End:

Best: Strong wind, deep thermocline, sunny and clear

Worst: Mild wind, shallow thermocline, cloudy and turbid

North End:

Best: Mild wind, shallow thermocline, sunny and clear

Worst: Strong wind, deep thermocline, cloudy and turbid

Strong wind, low light and a deep thermocline seem to reduce concentrations in the south end of the lake and increase concentrations in the north end through enhanced dilution and mass transport and attenuation of kinetic losses. Low wind, high light and a shallow thermocline promote higher concentrations in the south end and lower concentrations in the north end by minimizing dilution and mass transport and accentuating kinetic losses. (Canale, et. al. 1990). As shown in Tables 52 and 53, under the worst condition at the recreational sites the number of hours with fecal coliform counts greater that 200 are reduced from 49 to 14 during the June storm and totally eliminated during the July storm. Therefore the Regional Collection and treatment facilities would be very effective in reducing fecal coliform bacteria contamination.

The Regional facilities would reduce the external phosphorus loads from the combined sewer overflows by a minimum of 5 percent. Based on the storage in the swirl concentrators and the associated transmission lines this number could be increased to approximately 34 percent. The 1991 Moffa & Associates Report indicates that this number could be close to 50 percent. Using the stochastic total phosphorus model, the effect of these reductions and various other reductions on lake phosphorus concentrations was determined and are shown in Table 54. This analysis indicated that the predicted reductions in CSO phosphorus loads have little effect on lake phosphorus concentrations.

Table 54. Onondaga Lake Total Phosphorus Concentration With CSO Load Reductions

Condition:	Total Phosphorus Concentration mg/l
Existing	0.15
5% reduction in CSO load (1% reduction in external load)	0.15
35% reduction in CSO load (8% reduction in external load)	0.14
50% reduction in CSO load (11% reduction in external load)	0.13
100% reduction in CSO load (22% reduction in external load)	0.12

Nitrogen reductions resulting from the use of a regional collection system would be minor. According to the CSO Facilities Plan Update (Moffa, 1990), the CSO TKN load to the lake would be reduced by approximately 5 percent. This should have negligible effects on water quality since Onondaga Creek, Harbor Brook, and Ley Creek only contribute approximately 12 percent of the total annual TKN load and not all of that is attributable to the CSO's. Therefore, the overall TKN reduction would be less than 1 percent of the external load to Onondaga Lake.

The Regional Collection Facilities are projected to remove approximately 25 percent of the BOD-5 day loading from the combined sewer overflows, which would tend to increase the dissolved oxygen in the lake. If it is assumed that one-half of the BOD-5 day load in Onondaga Creek, Ley Creek and Harbor Brook is attributable to CSO's then the Regional Facilities would remove approximately 4 percent of the annual external load of BOD-5 day to Onondaga Lake.

The primary function of the swirl regulator/concentrators which are part of the Regional Collection and Treatment measure, is to remove gross solids and floatables as a preliminary step to further treatment, i.e. disinfection. In the case of disinfection, the swirl unit removes solids that can "harbor" bacteria so that it serves to physically remove a quantity of the pollutant material in question. Therefore, the transparency in Onondaga Lake would be slightly increased due to the use of the swirl regulator/concentrators. Moffa (1990) assumed 50 percent removal of CSO total suspended solids entering the lake from the combined sewer overflows.

Ammonia loads from CSO's were assumed to be reduced by 5 percent through use of the swirl regulator/concentrators. Again since the total load of Onondaga Creek, Ley Creek and Harbor Brook is only 5 percent of the annual load to the lake, the overall removal in the external load would be less than 1 percent.

The Regional Facilities would have negligible effects on the remaining parameters shown in Table 43 with the exception of some minor removals of heavy metals which may be associated with the solids.

This measure would significantly increase the suitability of Onondaga Lake for swimming but have negligible impacts on the fish habitat or the lake's suitability for use as a water supply source.

6.3.2 Centralized Collection and Treatment-Discharge to Onondaga Lake

The Centralized Collection and Treatment measure with discharge to Onondaga Lake eliminates the CSO discharges from the receiving creeks for all storm events less than the design event. The treated discharges would still be sent to Onondaga Lake. Therefore, the effects on the lake would be basically the same as previously discussed with the Regional Collection Facilities in Section 6.3.1 for all the parameters listed in Table 43.

6.3.3 Centralized Collection and Treatment-Discharge to Seneca River

The centralized collection and treatment scheme with discharge to the Seneca River would eliminate the majority of CSO related pollutant discharges to Onondaga Lake. Bacteria reductions would be similar to those discussed above for the Regional Facilities since those facilities are quite effective in their disinfection capabilities. Phosphorus loads from CSO's to Onondaga Lake would be reduced by 50 percent to 90 percent which is 11 percent to 20 percent of the total external loading. This would result in a lake phosphorus concentration of 0.13 to 0.12 mg/l as shown in Table 53. Total TKN loadings to the lake could be reduced by approximately 5 percent and BOD-5 day loadings could be reduced by approximately 10 percent to 15 percent which would help to increase the dissolved oxygen levels. Transparency would be increased due to the removal of the suspended solids associated with the CSO's and there would be slight reduction in the ammonia loading. There also could be a slight reduction in heavy metal loadings which may be associated with the solids. The remaining parameters should not be affected.

The Seneca River, Oswego River, and Lake Ontario would receive additional loadings of phosphorus, nitrogen, BOD-5 day, suspended solids, ammonia and minor amounts of heavy metals. The effects of these would have to be evaluated and addressed.

This measure would significantly increase the suitability of Onondaga Lake for swimming and result in minor improvements of the fish habitat and the lake's suitability for use as a water supply source.

6.4 Dredging and Disposal

The dredging and disposal measures will increase the levels of phosphorus and ammonia for a brief period during dredging. Assuming that dredging is performed when the conditions in the hypolimnion are anoxic, phosphorus will be released from the bottom sediments as they are disturbed and the sediment surface area increases. The sediment disturbance will also temporarily decrease the dissolved oxygen and transparency of the water. After the initial disturbance associated with dredging, the net result on phosphorus and ammonia will be a reduction in sediment release of these parameters and should increase through reduction in sediment oxygen demand. The dredging option will have a positive impact on the heavy metals (including mercury) and organics as they are removed with the sediments. Parameters such

as bacteria, ionic salts and productivity will not be affected by this alternative. The Seneca River will not be effected by dredging.

The dredging and disposal measure will have little effect on restoring the lake for swimming or for use as a water supply. The primary benefit this measure would have is reduction of the mercury concentration by removing the sediments.

6.5 Capping

The capping measure will reduce the sediment release of phosphorus, ammonia, heavy metals, organics and mercury as the contaminated sediments will be covered with cleaner material. Capping will have a negligible effect on productivity and no effect on bacteria, nitrogen, and ionic salts. Dissolved oxygen should increase through reductions in sediment oxygen demand. Transparency will be temporarily reduced because the capping process causes the disturbance of sediments into the water column. This measure will have no effect on the Seneca River.

As shown on Table 43, there would be little effect in restoring the lake for swimming. The only improvement in reaching the goals for water supply is shown as a reduction in the ammonia sediment release. Capping would aid in reaching the goals for ammonia and mercury concentrations in improving the environment for cold water fisheries.

6.6 Waste Beds

The waste bed remediation measures are discussed in greater detail in the report to Allied entitled Waste Bed Feasibility Study (Sections 1-4 and Sections 5-7). The capping of the waste beds will have no effect on the phosphorus, bacteria, dissolved oxygen, and productivity. The effect on the heavy metals and organics will be negligible. The capping of wastebeds will decrease the input of ammonia nitrogen by no more than 5 percent of the total external loads and a significant reduction of ionic salts (especially chloride) into the lake. Calcium carbonate precipitation should decrease with a resultant increase in transparency. It is not known at this time what the effect will be on the contribution of mercury. The Seneca River will receive a reduction in the loading of ionic salts which could eliminate chemical stratifrication in the river.

The waste bed remediation measures will have no effect on reaching the target goals for swimming. The effect that this will have on improving the fish habitat is a reduction in ammonia and chloride. At this time, it is not known how mercury will be affected. The waste bed remediation will also benefit in reaching the target goals for the water supply parameters of ammonia and chloride.

6.7 Mud Boils

The mud boils located in the watershed of Onondaga Creek impact the transparency of the creek itself as well as the lake. The high sediment load appears to be degrading the quality of Onondaga Creek as a fish habitat and spawning environment. The proposed measure to remediate the problem of high sediment loads includes removing the mud boil area from Onondaga Creek. This can be achieved by diverting the upper surface water drainage around the mud boil area. Groundwater that comes to the surface in the mud boil area and

creates heavy sediment loads will then be directed to a settling basin where the sediment can be trapped before it enters Onondaga Creek. The effect of this measure will be to improve the transparency of the creek and the lake. This increase in transparency may increase productivity and decrease dissolved oxygen. It may also enhance the mortality of fecal bacteria by sunlight transmitted to deeper waters. There will be no effect on the nitrogen, heavy metals, organics, ionic salts, or mercury. The effect on phosphorus will be negligible.

The mud boil measure will benefit the secchi depth transparency goal for the swimming restoration. It will have no effect on improving the parameters for water supply. However, it will improve the quality of the spawning area for fish.

6.8 In-Lake Oxygenation

The rehabilitation measure of in-lake oxygenation consists of artificially introducing pure oxygen into the hypolimnion during the summer thermal stratification period when the bottom lake waters tend to be void of dissolved oxygen. The object is to restore the oxygen level in the hypolimnion to values that would occur if the lake was oligotrophic or mesotrophic. The effects on various parameters and conditions are summarized in Table 43.

The bacteria problem in the lake is manifested by the introduction of raw sewage into the lake during storm events. The major contributors to the problem are the combined sewer overflows discharging into the creeks in the urban areas. The maintenance of dissolved oxygen in the bottom waters should have no effect on the bacterial concentrations, especially those existing in the epilimnion of the lake where the bacteria are introduced.

During anoxic conditions in the bottom waters, phosphorus and other nutrients are recycled from the bottom sediments. Because of the anoxic conditions, an internal source of phosphorus is added to the lake besides the external sources (tributaries, METRO, and CSO's). UFI calculated a phosphorus budget for the lake for the summer of 1987. The internal loads accounted for 22 percent of the total input phosphorus loading during that summer (Figure 99). On an annual basis because of higher tributary flows the internal loading would amount to about 12 percent of the total annual load based on the Corps' loading estimates. Through the process of oxygenation, this source could be reduced. The annual in-lake total phosphorus concentrations should decrease by about 11 percent to 0.13 mg/l as TP, which still would represent eutrophic conditions.

During the anoxic period, the ammonia concentration in the bottom waters increase due to the lack of oxygen and light thereby excluding any viable algae that would use the ammonia as a nitrogen source and the lack of nitrifying bacteria to reduce the ammonia to nitrates and nitrites. High ammonia concentrations in the epilimnion are a result of the METRO loads and the oversaturation of ammonia as a nitrogen source for the algae. The algae remove a great deal of ammonia from the upper waters. Restoring oxic conditions to the hypolimnion would decrease the hypolimnetic ammonia concentrations and increase the nitrite and nitrate concentrations. The general effect on the overall lake nitrogen concentration is presently unknown.

By applying the technique of in-lake oxygenation using pure oxygen during the stratification period, the dissolved oxygen concentration would be increased from zero to values at or near saturation for the temperatures of the hypolimnion. This amounts to approximately 12 mg/l at the onset of stratification to 10 mg/l at the beginning of fall overturn.

Under present lake conditions with an oxic hypolimnion (12% decrease in phosphorus loads), there may be no change in the productivity and transparency of the lake would still be in the hypereutrophic range of productivity.

As previously stated, the ammonia concentration in the hypolimnion would be decreased. UFI has calculated a total ammonia concentration of 0.27 mg NH_3-N/l would be required to avoid violation of acute and chronic toxicity criteria under critical conditions of pH and temperature. Target ammonia loads are shown to vary with rates of primary production (higher algal demand, more load permitted) and nitrification (higher nitrification, higher load permitted). Based on 1988- 1989 data the primary production for the lake is 1.59 gm $C \cdot m^{-2} \cdot d^{-1}$ (UFI, unpublished). For restoration purposes, primary production would have to have values from 0.25 -0.5 gm $C \cdot m^{-2} \cdot d^{-1}$ for oligotrophic and mesotrophic conditions. A steady state calculation (UFI) was done to estimate loading reductions required to achieve the ammonia target level of 0.27 mg/l with the primary productivity values of 1.59 (present) and 0.25 gm $C \cdot M^{-2} \cdot d^{-1}$ (future) under conditions of high nitrification and no nitrification. Under present productivity rates the total nitrogen loads would have to be decreased by 20 to 71 percent to reach the target level (0.27mg/l) under conditions of high nitrification and no nitrification and under future low productivity, these values would be 54 to 93 percent. This indicates that presently nitrogen removal at METRO would have to be 23 to 88 percent and for future conditions 63 to 110 percent (UFI, 1990).

Oxygenation of the hypolimnion would eliminate metals such as iron and magnesium from going into solution and also would oxidize and help prevent the build-up of hydrogen sulfide and methane gases.

Presently there is no information regarding the oxygen effects on heavy metals, mercury or organics (PCB's, etc) mobility. Oxygen would eliminate the buildup of sulfide species and the effect on this of mercury is presently unknown. These would be areas for future investigation and study.

The ionic problem encompasses lake problems regarding chlorides resulting from past and possibly present industrial discharges and leaching from wastebeds. The chlorides are associated with the metal ions of sodium, calcium and magnesium. Oxygenation of the hypolimnion would have no effect on the chloride concentration because it is a conservative substance.

During summertime low flow conditions, the lower layer of the Seneca River seems to act as an extension of Onondaga Lake and, thus, also suffers from depressed DO. Thus, oxygenation of the lake's hypolimnion would presumably improve the DO in the Seneca River as well. Increased oxygen levels could also cause release of calcium co-precipitated phosphorus from sediments.

This measure will not support the goals for producing acceptable swimming areas regarding increasing the water transparencies and decreasing the coliform bacteria concentrations. It would help to meet some of the goals of producing an acceptable cold water fishery in the hypolimnion during summer stratification. The goal of dissolved oxygen would be met, ammonia

concentrations could be reduced in the hypolimnion to a point where they would not be a problem and toxic to aquatic life, and nitrite-nitrogen concentrations could be maintained below problem concentrations. This would occur only during the stratification period because the METRO effluent is discharged into the surface waters. During periods of complete mixing, there could be ammonia and nitrite problems. Reduction in chloride concentrations and the removal of the sediment load from Onondaga Creek would not be realized. The hypolimnetic waters would reach the ammonia and nitrate and nitrite concentrations for drinking water standards, but the lake waters in general would not meet the standards for ammonia and possibly for the nitrite-nitrate.

6.9 In-lake Treatment

This rehabilitation measure of in-lake chemical treatment for Onondaga Lake consists of adding a chemical, in this case alum, $Al_2\ (SO4)_3 \cdot 14H_2O$, to the lake waters in order to strip the water column of some of its phosphorus content. In some cases, enough chemical is added to form a "sponge" over the bottom sediments for the purpose of soaking up any phosphorus release from the sediments. This technique is only effective in reducing the lake's phosphorus content if the external loads have been eliminated or greatly reduced. A one time application treatment for Onondaga Lake would cost at a minimum $8,000,000 for the alum alone. The effects of this measure on various parameters and conditions are summarized in Table 43.

The only effect this treatment might have on the bacteria could be some removal during floc formation and settling. There are no ways of ascertaining this other than possibly by laboratory testing. The effect would probably be negligible and only at the time of treatment.

Adding alum would cause a temporary decrease in lake total phosphorus concentration. Studies on other lakes indicates a reduction of up to 90 percent. A decrease of about 75 percent was documented for Irondequoit Bay with no change in pH or alkalinity (Monroe County Health Department, 1986). This would only be temporary because of the nutrient inputs from the tributaries and METRO. As time goes on the concentration will increase. Even though there is nutrient inactivation of the sediments, this is not permanent. Because of the influence of METRO's input, the phosphorus concentration is expected to increase fairly rapidly. Depending on the effect of sediment neutralization, it can be expected that the concentration would be back to the 0.13 mg/l level as a minimum in about a year and to 0.15 mg/l soon after, depending upon the effectiveness of sediment inactivation.

Because this treatment does not involve the nitrogen species there should be no effect on nitrate, nitrite and ammonia. Indirectly there could be some effect but this impact would be negligible.

Thru the process of removing phosphorus from the waters, if phosphorus becomes limiting and there is a decrease in algal production, there could be a slight increase in dissolved oxygen. This would result from less decaying algae and possible reductions in the sediment oxygen demand due to alum inactivation.

There could be a temporary increase in water transparency for two reasons. As the alum floc is used to extract the phosphorus, algae could also be removed thru the process. Also turbidity could be decreased by the

settling of fine grain inorganics (mud and calcium carbonate). The second cause would be a decrease in algae production due to the removal of phosphorus from the system. In either case, the possible increase in transparency would probably be temporary.

Under chemical treatment, there would be no change in ammonia or ammonia toxicity unless there is a change in pH which influences ammonia toxicity values. A decrease in pH would increase the ammonia toxicity concentration. It is anticipated the pH or ammonia would not be affected.

There might be a slight increase on the ionic conditions of the lake by the addition of aluminum and sulfate ions. There would not be any change in the chloride concentrations.

The effect of alum addition on heavy metals, organics, and mercury concentrations are generally unknown.

Once again, the influence on productivity is relative depending on the lake's position on the curve presented in Figure 98. There would be a reduction in phosphorus concentrations possibly followed by a decrease in productivity. This can be achieved by sliding down the curve in Figure 98 below point A by a decrease in phosphorus loads (internal) and the phosphorus in-lake concentrations. At this point it is not known whether this will occur It is known that the decrease in phosphorus concentrations will be temporary.

Generally, there should be no effect on the Seneca River water quality and problems. There would be a temporary decrease in total phosphorus loading to the Seneca River from Onondaga Lake Outlet however there would be no noticeable change in the river.

Table 45 shows that with respect to the goal for swimming, there could be a temporary increase in water transparencies above the state standards. This measure would not decrease the fecal coliform bacteria concentrations. For the cold water fishery goals, the only one temporarily affected is an increase in hypolimnion dissolved oxygen. It is not known whether this increase could be maintained above the level of 6 mg/l. It is not known how long this will last. The nitrogen problem would not be addressed and there would still be problems regarding ammonia and ammonia toxicity and possibly nitrite and/or nitrate problems. This measure would not decrease the mercury concentrations or chloride concentrations and would not address the Onondaga Creek sediment problems. As far as improving the lake as a drinking water source, there would not be any improvement.

5.10 Single Goal Alternatives

A summary of the measures that have been discussed to this point are shown in Table 55. Only the parameters presented in Table 43 that will be significantly impacted by the given measure have been included in Table 55. The restoration goals that are effected by the associated measures are addressed in Table 55 with an estimation of the costs. The various individual measures have been combined to produce the minimum first steps to achieve the restoration goals presented in Table 45. Table 56 presents a summary of the measures necessary to obtain the single goal alternatives. The measures making up the alternatives have been discussed in previous chapters. Dredging and disposal and capping are relatively costly measures that address only the mercury problem. These measures should be given further consideration when

TABLE 55 - Summary Table of Lake Rehabilitation Measures, Selected Parameters, Goals Addressed, and Cost estimates.

LAKE REHABILITATION MEASURES	BACTERIA	PHOSPHORUS	NITROGEN	DO	TRANSPARENCY	MERCURY	CHLORIDE	GOALS ADDRESSED	COSTS (MILLION $)
METRO									
PHOSPHORUS REMOVAL	-	XXXXX	-	XXXXX	XXXXX	-	-	S,F,D	-
NITROGEN & AMMONIA REMOVAL	-	-	XXXXX	XXXXX	-	-	-	S,F,D	-
DISCHARGE TO SENECA RIVER	-	XXXXX	XXXXX	XXXXX	XXXXX	-	-	S,F,D	-
CSO's									
REGIONAL COLLECTION & TREATMENT	XXXXX	-	-	-	XXXXX	-	-	S	-
CENTRALIZED COLLECTION & TREATMENT DISCHARGE TO ONONDAGA LAKE	XXXXX	-	-	-	XXXXX	-	-	S	-
CENTRALIZED COLLECTION & TREATMENT DISCHARGE TO SENECA RIVER	XXXXX	-	-	-	XXXXX	-	-	S	-
DREDGING & DISPOSAL	-	-	-	-	-	XXXXX	-	F	19.1 - 61.7
CAPPING	-	-	-	-	-	XXXXX	-	F	143 - 341
WASTE BEDS	-	-	-	-	-	-	XXXXX	F,D	0.2 - 250
MUD BOILS	-	-	-	-	XXXXX	-	-	F,S	0.35 + 0.07A
IN-LAKE OXYGENATION	-	-	-	XXXXX	-	-	-	F	0.7 + 0.8A
IN-LAKE TREATMENT	-	XXXXX	-	-	XXXXX	-	-	S,F	0.08 + 12A

1) S =SWIMMING, F = FISHERY, D = DRINKING WATER,
Note that the goals are addressed but not necessarily achieved
2) A = ANNUAL COST

additional information becomes available regarding necessary sources and cycling. In-lake chemical treatment is a measure whose effectiveness is only temporary and the reduction of in-lake phosphorus concentrations may not result in noticeable reductions in algal growth or noticeable lake recovery. The METRO diversion around Onondaga Lake will have a positive impact on the lake's water quality, however, the magnitude of the effect on the Seneca River as well as on the downstream Oswego River and Harbor is unknown at this time.

The minimum first steps to achieve bathing beaches that meet New York State standards require the control of CSO's, additional removal of phosphorus by METRO or METRO diversion, control of the mud boils, and in-lake oxygenation. The regional collection and treatment of CSO's will reduce the average number of days per year that the coliform standards are exceeded from approximately 40 to approximately 3. The oxygenation will reduce the phosphorus leached out of the sediments reducing the total phosphorus load to the lake by about 12%. The effect that this will have on the transparency cannot be determined until the transparency model is ready and available by UFI.

The minimum first steps toward development of a cold water fishery requires additional phosphorus removal and advanced treatment for nitrogen removal (ammonia nitrification and denitrification at METRO or the METRO diversion), in-lake oxygenation, the removal of excessive chloride inputs from the waste beds, and sediment control of the mud boils. The lake will benefit from the additional removal of phosphorus thru METRO, however, with the reduction as low as 0.1 mg/l of P, the lake will remain in a eutrophic state. The in-lake oxygenation will reduce the in-lake production of phosphorus and will eliminate the ammonia problems in the hypolimnion. The advanced treatment of nitrogen, depending upon the achieved level, could reduce the algal productivity, eliminate the ammonia and nitrite toxicity problems, increase the transparency, and increase the amount of dissolved oxygen in the hypolimnion. However, if nitrogen becomes limiting, a problem could develop with bluegreen algae. The removal of chlorides thru the Allied Chemical waste bed remediations will bring the in-lake chloride concentrations within New York State DEC standards for cold water fisheries. The control of the mud boils will reduce the lake's most significant contributor of fine grained sediment and therefore increase transparencies in Onondaga Creek and the southern end of Onondaga Lake.

The minimum first steps to achieve water quality such that the lake could serve as a water supply with a reasonable amount of treatment include the additional removal of phosphorus by METRO or the METRO diversion, the removal of chlorides, in-lake oxygenation, and the elimination of the ammonia problems thru nitrification at METRO. Denitrification in the METRO effluent may be necessary to reduce nitrate concentrations in the lake.

6.11 Multiple Goal Alternatives

An assessment was made based on various combinations of the three goals presented in Table 56. For each multiple goal alternative, the combined measures that will produce the most reasonable first steps to achieve these combined goals are discussed in the following section. It must be noted that the potential exists for antagonistic impacts of combined remediation. For example, options that improve transparency coupled with those that increase dissolved oxygen and enhance nitrification (which increases NO2/NO3) might cause more algal production. Table 57 shows a summary of the multiple goal alternatives.

The first alternative is a combination of the swimming and fishing goals. The minimum first steps to achieve this alternative include controlling the CSO's, the additional removal of phosphorus and ammonia nitrification and denitrification at METRO or the METRO diversion , the control of the Onondaga Creek sediment source at the mud boils, in-lake oxygenation, remediation of waste beds, and control of excessive chloride inputs from the waste beds. The CSO control is required to remove the coliform bacteria level so that the New York State DOH standards for bathing beaches can be met. The additional phosphorus removal is necessary to reduce the algal productivity and decay, reduce the high sediment oxygen demand, and increase the water transparency. The in-lake oxygenation also will provide the dissolved oxygen in the hypolimnion for the fish. This measure will reduce the nutrients and metals from leaching out of the sediments. The production of hydrogen sulfide and methane gases will be eliminated and the ammonia concentrations will be reduced. Controlling the mud boils as a source of sediment is required to improve the transparency for both the swimming and fishing goals. The nitrification and denitrification at METRO is required to reduce the nitrite and ammonia levels in order to achieve the fishing goal. This may also help reduce the algal productivity. Transparency may be improved and the reduction in algal production will have a positive effect on the dissolved oxygen in the hypolimnion. The chloride control should bring the in-lake chloride concentrations within New York State DEC standards for cold water fisheries.

Table 56. Single Goal Alternatives

Goal		Costs (million $) First Cost	Annual Cost	**Combined Measures***
Swimming				o CSO Control
				o Additional P Removal -METRO
		0.35	.07 A	o Sediment Control-Mud boils
		0.7	0.8 A	o In-lake Oxygenation
	Total			
Cold Water Fishery**				o Additional P Removal - METRO
		0.35	.07 A	o Sediment Control-Mud boils
		0.7	0.8 A	o In-lake Oxygenation
				o Ammonia Nitrification-Denitrification METRO
		0.2-250		o Chloride Control -Waste Beds
	Total			
Drinking				o Additional P Removal -METRO
		0.7	0.8 A	o In-lake Oxygenation
				o Ammonia Nitrification -METRO (Possible Denitrification)
		0.2-250		o Chloride Control-Waste Beds
	Total			

* The METRO diversion would satisfy additional phosphorus removals and ammonia nitrification and denitrification at METRO

** The measures to achieve the fishing goal do not include the mercury issue due to the lack of information at this time.

The second multiple goal alternative is a combination of swimming and drinking. The minimum first steps to achieve this alternative include CSO control, sediment control at the mud boils, additional phosphorus removal and ammonia nitrification and possible denitrification at METRO or the METRO diversion , in-lake oxygenation, and chloride input control. The measures for this alternative will have the same effects as those discussed for the previous alternative.

A third multiple goal alternative consists of a combination of fishing and drinking. The minimum first steps to achieve this alternative include additional phosphorus removal and ammonia nitrification with possible denitrification at METRO or the METRO diversion, sediment control at the mud boils, in-lake oxygenation, remediation of the waste beds. The effects that each of the measures would have in achieving the goal has been discussed in the previous paragraphs.

The fourth multiple goal alternative includes a combination of swimming, fishing and drinking. The minimum first steps to achieve this alternative include CSO control, additional phosphorus removal and ammonia nitrification and denitrification at METRO or the METRO diversion, control of the sediment source at the mud boils, in-lake oxygenation, remediation of the waste beds. This alternative has the same combination of measures as the swimming and cold water fishery alternative. The effect that each measure has with respect to reaching the goal has been previously discussed.

Table 57. Multiple Goal Alternatives

Goal	Costs (million $) First Cost	Annual Cost	Combined Measures*
Swimming			o CSO Control
Cold Water			o Additional P Removal-METRO
Fishery**	0.35	0.07A	o Sediment Control-Mud Boils
	0.7	0.8A	o In-lake Oxygenation
			o Ammonia Nitrification and Denitrification-METRO
	0.2-250		o Chloride Control-Waste Beds
Total			
Swimming			o CSO Control
Drinking			o Additional P Removal - METRO
	0.35	0.07A	o Sediment Control- Mud Boils
	0.7	0.8A	o In-lake Oxygenation
			o Ammonia Nitrification-METRO possible denitrification
	0.2-250		o Chloride Control-Waste Beds

(Con't) **Table 57**

Goal	**Costs (million $)** First Cost	Annual Cost	**Combined Measures***
Total			
Cold Water			o Additional P Removal
Fishery**	0.35	0.07A	o Sediment Control-Mud Boils
Drinking	0.7	0.8A	o In-lake Oxygenation
			o Ammonia Nitrification and Denitrification-METRO
	0.2-250		o Chloride Control-Waste Beds
Total			
Swimming			o CSO Control
Cold Water			o Additional P Removal - METRO
Fishery**	0.35	0.07A	o Sediment Control-Mud Boils
Drinking	0.7	0.8A	o In-lake Oxygenation
			o Ammonia Nitrification
			o and Denitrification-METRO
	0.2-250		o Chloride Control-Waste Beds
Total			

* The METRO diversion would satisfy additional phosphorus removal and ammonia nitrification and denitrification at METRO.

** This alternative does not include the mercury issue because information is not available at this time.

7. CONCLUSIONS

Table 58 is a summary of the water quality problems on Onondaga Lake, their causes or sources and the consequences of these problems.

Table 58. Summary of Problems, Causes and Consequences

Problems	Causes or Sources	Consequences
DO Depletion in hypolimnion	hypereutrophy from high nutrient loads/levels	o cannot maintain cold water fishery o excessive nutrients and metals leaching from sediments o production of hydrogen sulfide and methane gases o high ammonia concentrations
Excessively High Phosphorus loads	Discharges from METRO & CSO'S Internal sediment release	o high algal productivity o algal decay depletes DO o creates high sediment oxygen demand o decreased transparency
Excessively High Nitrogen loads/ levels	Discharge from METRO	o high algal productivity o ammonia toxicity o nitrite toxicity o decreased transparency o algal decay depletes DO
High Chloride Concentration	Former industrial discharges & leaching from waste beds	o Contravenes NY State Standards for fishing and drinking
Sediment Discharge	Mud boils	o No fish from Onondaga Creek populations below mud boils o decreased lake transparency
High Fecal Coliform Bacteria loads	CSO's	o Contravention of state standards for swimming during storm events
High Mercury Concentrations in fish	Former Industrial discharges	o High Sediment concentrations accumulated in aquatic life

The restoration goals, which have been previously discussed, are shown below.

<u>Produce Acceptable</u>

<u>Swimming Areas</u>

o Increase transparencies to values greater than state standards

o Decrease total coliform and fecal coliform bacteria counts to values below state standards

<u>Produce Acceptable</u>

<u>Cold Water Fishery</u>

o Reduce average total ammonia concentration to level below 0.27 mg/1. Maintain total fixed inorganic nitrogen >0.05 mg N/1 to avoid proliferation of nuisance bluegreen algae.

o Increase hypolimnion DO to a minimum of 5 mg/1 (daily average of 6 mg/1) at any point in the bottom waters and attempt to maintain levels at a value close to saturation during summe stratification

o Decrease Hg concentrations in water to a point where accumulation in the aquatic community is minimal

o Reduce and maintain nitrite-nitrogen concentrations below state standard of 0.02 mg/1

o Reduce current chloride concentrations below 250 mg/1

o Remove the Onondaga Creek sediment discharge and reduce creek and lake turbidity thru remedial action on the mud boils.

<u>Produce an Acceptable</u>

<u>Drinking Water Supply with Minimum Treatment</u>

o Reduce and maintain total ammonia concentration to levels below the drinking water standards of 2.06 mg/1 at a Ph of 7.25 and temperature of 20^{o} C.

o Maintain nitrite & nitrate-nitrogen concentrations at levels below state drinking water standards of 10 mg/1 for both

o Reduce chlorides to a level below 250 mg/1

o Maintain DO in hypolimnion above state standards of 4 mg/1 (daily average of 5 mg/1)

The conclusions that have been developed from this water quality analysis are listed below:

1. The most effective measure to reduce pollutant loads to the lake is re-routing of METRO discharge. However, this could have detrimental effects on the Seneca River and additional pollution abatement measures would be necessary. Current modeling efforts are addressing this issue.

2. Reduction/elimination of METRO total phosphorus discharge (which is a major source of nutrients) will not shift the lake conditions out of the eutrophic state, however, improvements would be noticeable.

3. Ammonia controls at METRO including nitrification and a reduction in ammonia due to oxygenation will help in achieving the cold water fish habitat goal as well as the drinking water goal.

4. CSO's must be treated to achieve the swimming goal due to their discharge of coliform bacteria.

5. The least cost bacteria reduction measure is regional collection and treatment.

6. CSO pollution reduction measures reviewed in this report have minor effects on phosphorus loads to the lake.

7. Dredging and capping measures which address mercury in the sediment, are very costly with uncertain improvements and undefinable benefits.

8. Remedial control of waste beds is necessary to bring in-lake chloride concentrations to within state standards.

9. Mud boil sediment load must be reduced significantly to enable fish spawning in Onondaga Creek and increase transparency in the lake.

10. In-lake oxygenation is a measure that will result in noticeable improvements to the lake. These improvements include reduced nutrient and metal leaching from the sediments, a reduction of methane gases, a reduction in ammonia from the hypolimnion, and enough dissolved oxygen to maintain a cold water fish population in the lake. Its effect on mercury release from the sediments and ultimate uptake by fish is unknown.

11. In-lake chemical treatment for phosphorus removal is very costly and its benefits are temporary unless the external sources are removed.

12. There is not enough information on the mercury to determine the sources or the mechanism that causes it to cycle out of the sediments.

13. There is little information on organics in the lake regarding how they interact between the sediments, water, and aquatic life. More studies are needed in this area to better define the organic relations with this environment.

14. If actions are taken to improve water quality and develop a cold water fishery without additional actions to deal with in-place contaminants, fish would still be inedible.

15. The current modeling efforts by the Upstate Freshwater Institute need to be completed before an efficient solution can be formulated. These efforts are needed to predict how the lake will respond to changes in nutrient and pollutant loadings. There is need to quantify the load reductions that each measure will have on a specific pollutant or nutrient. The lake models use this input to determine how the lake will respond to proposed loading changes.

8. ADDITIONAL STUDIES

Several issues regarding the cleanup of Onondaga Lake cannot be adequately addressed because additional information is required. The following additional studies are recommended in order to more thoroughly evaluate these problems:

1. The Chemistry and Cycling of Me-:ury in Onondaga Lake.

Onondaga Lake was closed to fishing in 1970 due to mercury contamination of fish flesh. Decreases in the concentrations of mercury in the fish have been achieved, however, significant numbers of the legal-size fish continue to exceed the U.S. Food and Drug Administration limit of 1 ppm. The closing of the chlor-alkali manufacturer eliminated the major discharge of mercury to the lake, however, mercury is still entering the food-chain either by recycling from the large reservoir in the sediments or from continuing inputs from tributaries or both.

Mercury exhibits a variety of forms in natural waters including free mercuric iron, mercuric complex of chloride, hydroxide and sulfide, monomethyl mercury complexes as well as elemental mercury. These species, in turn regulate the transport and bioavailability of mercury. Methyl-mercury (which accumulates in fish tissue) formation is dependent upon the concentration of free mercury.

There have been changes in the chemistry of Onondaga Lake in recent years. Sulfide concentrations in the hypolimnion during anoxic conditions have decreased. Chloride concentrations have decreased. Increases in dissolved oxygen will further decrease sulfide concentrations. These changes affect free mercuric ion concentrations and can effect the bioavailability of mercury.

These studies will determine the following:

a. Sources of mercury.
b. Sediment contribution under aerobic and anaerobic conditions.
c. The effect of increased oxygen in the hypolinmion on methyl mercury formation.
d. The quantity and effects of mercury exiting Onondaga Lake and migrating to downstream areas such as the Oswego River Area of Concern.

2. Hydrogeologic Cause of the Mud Boils.

The mud boils are a phenomenon that are produced by artesian water pressure flowing to the surface with a heavy sediment load. A hydrogeologic assessment of the area is necessary to determine groundwater flow direction and magnitude. The mud boils should be monitored through the seasons to determine the variability in flow, and sediment concentration. The upstream tributary capture will be verified and options to redirect the flow will be considered.

3. The Chemistry and Cycling of Organics.

Benzene and chlorinated hydrocarbon waste associated with the production of chlorobenzene by the chlor-alkali manufacture enters the lake via the groundwater. Benzene and chlorinated hydrocarbons have been found in lake sediments and fish flesh. PCB's have been found in sediments of Onondaga Lake tributaries. However, detailed studies have never been conducted to document the extent and dynamics of this contamination, the cycling of these materials within the lake and its food chain and to establish the environmental effects and risks of this contamination.

A detailed documentation of the contamination of the sediments is needed. The areal and vertical character of the contamination through the collection of sediment cores and subsequent chemical analysis is necessary.

A detailed documentation of fish flesh contamination should be assessed for all major species with the age/contaminant relationship assessed. The status with respect to standards should also be determined.

4. Water Quality Monitoring During Hypolimnetic Oxygenation

During anoxic conditions in the bottom waters phosphorus and other nutrients are recycled from the bottom sediment. It has been calculated that the internal phosphorus loading would amount to about 12 percent of the total annual load based on the Corps' loading estimates. Through the process of oxygenation, this source would be and reduced. Theoretically, the annual in-lake total phosphorus concentrations should decrease by about 12 percent. Current existing conditions modeling gives an average concentration of 0.15 mg/l. Under oxic conditions, the value drops to 0.13 mg/l.

During the anoxic period, the ammonia concentration in the bottom waters increases due to the lack of oxygen and light thereby excluding any viable algae that would use the ammonia as a nitrogen source and the lack of nitrifying bacteria to reduce the ammonia to nitrates and nitrites. Restoring oxic conditions to the hypolimnion should decrease the hypolimnetic ammonia concentrations and increase the nitrite and nitrate concentrations.

By applying the technique of in-lake oxygenation using pure oxygen during the stratification period, the dissolved oxygen concentration would be increased from zero to values at or near saturation for the temperatures of the hypolimnion. This amounts to approximately 12 mg/l at the onset of stratification to 10 mg/l at the beginning of fall overturn.

Oxygenation of the hypolimnion would eliminate metals such as iron and magnesium from going into solution. The effect on the heavy metals is unknown. Oxygen would oxidize and help prevent the built-up of hydrogen sulfide and methane gases.

There is very little information on mercury. Available literature indicates the concentration of the free mercuric iron may increase, however, the lack of anoxic conditions may stabilize the mercury in the metal form and decrease or prevent it from being converted to the organic form.

5. <u>Detailed Analysis and Design of Diversion Channel and Settling Basin for Sediment Control Remediation.</u>

A detailed analysis will be required to more accurately determine the settling characteristics of the sediment originating from the mud boils. In addition, a stream-gaging program will be required to determine the flow characteristics and flow volumes of the mud boils when separated from the natural tributary which currently drains them. Stability analyses should be conducted to determine if the selected site is appropriate. Based on these analyses the channel and settling basin designs will have to be refined.

6. <u>Alternative Mudboil Remediation Analyses</u>.

Further investigation of alternatives for remediation of mudboil effluent including:

a. Depressurizing wells.

b. Subsurface grouting of mudboil areas.

c. Recirculation of effluent.

d. Construction of a dam immediately downstream of the main mudboil area to create sufficient overlying hydrostatic load to prevent the mudboil discharges.

e. Upgradient sealing of transmissive units.

f. Mudboil flow diversion.

REFERENCES

1. Allied-Signal, Inc., 1990, Waste Bed Feasibility Study (Sections 1-4), Draft Allied-Signal, Inc., Solvay, New York.

2. Auer, M.T., 1989, Monitoring Fecal Coliform Bacteria in Onondaga Lake and Its Tributaries - 1987, Upstate Freshwater Institute.

3. Auer, M.T. and Johnson, N.A., 1989, Phosphorus Release from Onondaga Lake Sediments, Upstate Freshwater Institute, p. 29.

4. Auer, M.T., and Niehaus, S.L., 1989, Fecal Coliform Bacteria Kinetics in Onondaga Lake, New York, 1989, Upstate Freshwater Institute, p. 49.

5. Auer, M.T. and Storey, M.L., 1989, Growth Kinetics of Onondaga Lake Phytoplankton, Upstate Freshwater Institute, p. 50.

6. Auer, M.T., Storey, M.L., Effler, S.W., and Auer, N.A., 1988, Zooplankton Impacts on Chlorophyll and Transparency in Onondaga Lake, New York, USA, 1988, Upstate Freshwater Institute, p. 31.

7. Auer, M.T. and Brooks, C.M., 1988, Determination of Nitrogen Kinetics in Laboratory Microcosms, Upstate Freshwater Institute, p. 21.

8. Averett, D.E., Perry, B.D., and Torrey, E.J., 1989, Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes, Draft Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

9. Bengtsson, L., Meyer, O., and Verner, B., 1972, Restauerering av Sjor med Kulturbetingat Hypolimniskt, Limnologiska Institutioner, LundUniversitet, Centrala Fysiktaboratoriet, Atla Copco AB, Sweden

10. Bernhard, H., 1974, Ten Years Experience on Reservoir Aeration, Presented at the 7th International Conference on Water Pollution Research, Paris, France.

11. Bernhardt, H., 1967, Aeration of Wahnbach Reservoir Without Changing the Temperature Profile, Journal of American Water Works Association, 59: 943-964.

12. Bjork, S., 1974, European Lake Rehabilitation Activities, Presented at the Conference on Lake Protection and Management, Madison, Wisconsin.

13. Blasland and Bouck Engineers, 1990, Waste Bed Feasibility Study.

14. Blasland and Bouck Engineers, 1989, Hydrogeologic Assessment of the Allied Waste Beds in Syracuse Area, Volume 1.

15. Bloom, N.S. and Effler, S.W., 1990, Seasonal Variability in the Mercury Speculation of Onondaga Lake, New York, Upstate Freshwater Institute.

16. Bloomfield, J.A., 1979, Lakes of New York State, Vol. 11, Ecology of the Lakes of Western New York, p. 223-365.

17. Brooks, C.M. and Effler, S.W., 1989, The Distribution of Selected Nitrogen Species in Onondaga Lake, New York, Upstate Freshwater Institute, p. 124.

18. Browman, M.G., Harris, R.F., and Armstrong, D.E., 1977. Interaction of soluble phosphate with aluminum hydroxide in lakes. Tech. Report No. 77-05, Water Resources Center, University of Wisconsin, Madison, Wisconsin.

19. Calocerinos and Spina, 1985, Onondaga Lake Monitoring Program, 1984.

20. Calocerinos and Spina, 1984, Onondaga Lake Monitoring Program, 1983.

21. Calocerinos and Spina, 1983, Facilities Plan for In-Water Combined Sewer Overflow Abatement.

22. Calocerinos and Spina, 1983, Onondaga Lake Monitoring Program, 1982.

23. Calocerinos and Spina, 1982, Onondaga Lake Monitoring Program, 1981.

24. Canale, R. and Effler, S.W., 1989, Stochastic Phosphorus Model for Onondaga Lake, Water Resources, Volume 23, No. 8, p. 1009-1016.

25. Canale, R.P., Owens, E.M., Auer, M.T., Heidtke, T.M., and Effler, S.W., 1990, Modeling Fecal Coliform Bacteria Contamination in Onondaga Lake, UFI.

26. Connor, J.N. and Smith, G.N., 1986, An Effective Method of Applying Aluminum Salts for Sediment Phosphorus Inactivation in Lakes, Water Resources Bulletin, Volume 22, No. 4, P. 661-664.

27. Cook, G.D., Heath, R.T., Kennedy, R.H., McComas, M.R., 1978, Effects of Diversion and Alum Application on Two Eutrophic Lakes, EPA-800-3-78- 033.

28. Cook, G.D., Kennedy, R.H., 1981, Precipitation and Inactivation of Phosphorus as a Lake Restoration Technique, EPA-600-3-81-012.

29. Department of the Army, 1987, Disposal Alternatives for PCB-Contaminated Sediments From Indiana Harbor, Indiana, Volume 1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

30. Department of the Army, 1983, Dredging and Dredged Material Disposal, Engineer Manual EM 1110-2-5025, Department of the Army, U.S. Army Corps of Engineers, Washington, DC.

31. Devan, S. and Effler, S.W., 1984, History of Phosphorus Loading to Onondaga Lake, Journal of Environmental Engineering, Volume 110, No. 1, p. 93-109.

32. Effler, S.W., Brooks, C.M., Auer, M.T., and Doerr, S.M., 1990, Free Ammonia and Toxicity Criteria in a Polluted Urban Lake, Upstate Freshwater Institute.

33. Effler, S.W., Johnson, D.L., Jiao, J.F., and Perkins, M.G., 1989, Optical Impacts and Sources of Tripton in Onondaga Creek, USA, Upstate Freshwater Institute.

34. Effler, S.W., 1988, Secchi Disc Transparency and Turbidity, Journal of Environmental Engineering, Volume 114, No. 6.

35. Effler, S.W., Hassett, J.P., Auer, M.T., and Johnson, N., 1987, Depletion of Epilimnetic Oxygen and Accumulation of Hydrogen Sulfide in the Hypolimnion of Onondaga Lake, New York, Water, Air, and Soil Pollution.

36. Effler, S.W., Perkins, M.G., and Brooks, C., 1986, The Oxygen Resources of the Hypolimnion of Ionically Enriched Onondaga Lake, New York, Water, Air, and Soil Pollution, Volume 29, p. 93-108.

37. Effler, S.W., 1987, Hypereutrophy and Pollution in Onondaga Lake, New York, American Water Resources Association, Upstate Freshwater Institute.

38. Effler, S.W. and Owens, E.M., 1987, Modifications in Phosphorus Loading to Onondaga Lake, USA, Associated with Alkali Manufacturing, P. 177-182.

39. Effler, S.W., 1986, The Impact of a Chlor-Alkali Plant on Onondaga Lake and Adjoining Systems, Water, Air, and Soil Pollution.

40. Effler, S.W., and Driscoll, C.T., 1986, A Chloride Budget for Onondaga Lake, New York, USA, Water, Air, Soil Poll, p. 27 & 29-44.

41. Effler, S.W., Schimel, K., and Millero, F.J., 1986, Salinity, Chloride, and Density Relationships in Ion Enriched Onondaga Lake, New York, Upstate Freshwater Institute, No. 40.

42. Effler, S.W., Driscoll, C.T., Wodka, M.C., Honstein, R., Devan, S.P., Jaran, P., and Edwards, T., 1985, Phosphorus Cycling in Ionically Polluted Onondaga Lake, New York, Water, Air, and Soil Pollution.

43. Effler, S.W., Wodka, M., and Field, S., 1984, Scattering and Adsorption of Light in Onondaga Lake, Environmental Engineering, Volume 110, No. 6, p. 1134-1145.

44. Effler, S.W., Field, S.D., Meyer, M.A., and Sze, P., 1981, Response of Onondaga Lake to Restoration Efforts, Journal of Environmental Engineering Division, Volume 107, p. 191-210.

45. Eisenrich, S.J., Atmstrong, D.E., and Harris, R.F., 1977. A Chemical Investigation of Phosphorus Removal in Lakes by Aluminum Hydroxide. Tech. Report, Wisconsin Water Resources Center, No. 77-02. University of Wisconsin, Madison, Wisconsin.

46. Fast, A.W., and Lorenzen, M.W., 1976, Synoptic Survey of Hypolimnetic Aeration, Journal of the Environmental Engineering Division, American Society of Civil Engineers, p. 1161-1173.

47. Fast, A.W., Lorenzen, M.W., and Glen, J.H., 1976, Hypolimnetic Aeration/Oxygenation: A Comparative Study With Costs, Journal of the Environmental Engineering Division, American Society of Civil Engineers, p. 1161-1173.

48. Fast, A.W., Overholtz, W.J., and Tubb, R.A., 1975, Hypolimnetic Oxygenation Using Liquid Oxygen, Water Resources Research, 11(2): 294-299.

49. Fast, A.W., Dorr, V.A., and Rosen, R.J., 1975, A Submerged Hypolimnion Aerator, Water Resources Research, 11(2): 287-293.

50. Fast, A.W., 1973a, Effects of Artificial Hypolimnion Aeration or Rainbow Trout (Salmo gairdneri Richardson) Depth Distribution, Transactions of American Fisheries Society, 102(4): 715-722.

51. Fast, A.W., 1973b, Review of Three Hypolimnetic Aeration Projects, News Release, Union Carbide Corporation, New York, New York.

52. Fast, A.W., 1971, The Effects of Artificial Aeration on Lake Ecology, Water Pollution Control Series 16010 EXE 12/71, Environmental Protection Agency, Washington, DC.

53. Freeman, R.A., and Everhard, W.H., 1971, Toxicity of Aluminum Hydroxide Complexes in Neutral and Basic Media to Rainbow Trout, Trans. Amer. Fish Soc. 100: 644-658.

54. Getchell, F.A., 1982, Subsidence in the Tully Valley, New York, MSC Thesis, Syracuse University.

55. Hayes, D.F., McLellan, T.N., and Truitt, C.L., 1988, Demonstrations of Innovative and Conventional Dredging Equipment at Calumet Harbor, Illinois, Miscellaneous Paper EL-88-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

56. Hayes, D.F., Raymond, G.L., and McLellan, T.N., 1984, Sediment Resuspension from Dredging Activities, Proceedings of the Conference Dredging '84, Dredging and Dredged Material Disposal, American Society of Civil Engineers, Clearwater, Florida, Volume I, p. 73-82.

57. Heidke, T.M., 1989, Onondaga Lake Loading Analysis: Total Phosphorus, Upstate Freshwater Institute, p. 124.

58. Heidke, T.M., 1989, Onondaga Lake Loading Analysis: Fecal Coliforms, Upstate Freshwater Institute.

59. Hennigan, R.D., 1989, America's Dirties Lake, Clearwater, Florida, Volume 19, No. 4, p. 8-12.

60. Holland, J.P. and Tate, C.H., Jr., 1984, Investigation and Discussion of Techniques for Hypolimnion Aeration/Oxygenation, Technical Report E-84-10, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi.

61. International Joint Commission, 1988, Options for the Remediations of Contaminated Sediments in the Great Lakes, Sediment Subcommittee, International Joint Commission, Windsor, Ontario.

62. Johnson, D.L., 1989, Individual Particle Analysis and Transparency in Onondaga Lake 1987, Upstate Freshwater Institute, p. 21.

63. Kaneko, A., Watari, Y., and Aritomi, N. In press. The Specialized Dredges Designed for the Bottom Sediment Dredging, Proceeding of the 8th U.S./Japan Experts Conference on Toxic Bottom Sediments, Tokyo, Japan, November 1982, U.S. Army Engineer Water Resources Support Center, Fort Belvoir, Virginia. July 1984.

64. Kennedy, R.H., and Cooke, G.D., 1982, Control of Lake Phosphorus with Aluminum Sulfate: Dose Determination and Application Techniques, Water Resources Bulletin, Vol 18, No. 3, American Water Resources Assoc., p. 389-395.

65. Kennedy, R.H., 1978, Nutrient Inactivation With Aluminum Sulfate As a Lake Restoration Technique PhD Disertation, Kent State, p. 292.

66. Lorenzen, M. and Fast, A., 1977, A Guide to Aeration/Circulation Techniques for Lake Management, Tetra Tech, Inc. Lafayette, CA.

67. Moffa and Associates, 1990, Memorandum Re: Onondaga Creek Phosphorus Loadings, Summary of February 9, 1990 Meeting at Albany NYSDEC.

68. Moffa and Associates, 1990, Combined Sewer Overflow Facilities Plan Update.

69. Moffa and Associates , 1991, Combined Sewer Overflow Factilities Plan.

70. Moffa, P.E., Deguida, R.N., Geldof, N., and Ott, R., 1990, Water Quality Impacts from Combined Sewer Overflow and Non-Point Source Discharges and Resulting Abatement Strategies.

71. Moffa, P.E., 1987, Onondaga Lake ....The Future, Technologist, p. 2.

72. Moffa, P.E., 1987, When Will We Swim in Onondaga Lake? Early History, No. 1 of 4, Technologist, p. 2.

73. Moffa, P.E., 1987, Pollution Abatement for Onondaga Lake, No. 3 of 4, Technologist, p. 3.

74. Monroe County Health Department, 1986, Irondequoit Bay Phase II Clean Lakes Project.

75. Murphy, C.B. Jr. 1978. Onondaga Lake. pp 224-365 in J.A. Bloomfield (ed.) Lakes of New York State, V. II, Ecology of the Lakes of Western New York. Academic Press, Inc. NY.

76. Murphy, T., 1987, Report on the Water Oxygenation Trial at Hamilton Harbor.

77. New England Division (NED), U.S. Army Corps of Engineers, 1989, New Bedford Harbor Superfund Pilot Study, Evaluation of Dredging and Dredged Material Disposal, Waltham, Massachusetts.

78. New York State Department of Environmental Conservation, 1989, Engineering Investigations at Inactive Hazardous Waste Sites, Phase II Investigation. Mercury Sediments-Onondaga Lake, Volume 1, Albany, New York.

79. O'Brien and Gere, 1979, Combined Sewer Overflow Abatement Program.

80. Clean Water Act, Section 314, Grant Proposal.

81. Onondaga County, 1971, Onondaga Lake Study, Environmental Protection Agency, Water Quality Office, Water Pollution Con Research Series, p. 487.

82. Overholtz, W.J., 1975, An Ecological Evaluation of Hypolimnetic Oxygenation by the Side Stream Pumping Process at Ottoville Quarry, Ottoville, Ohio, M.S. Thesis, Ohio State University, Columbus, Ohio.

83. Owens, E.M. and Effler, S.W., 1985, A Stratification Model for Onondaga Lake, New York, Central New York Regional Planning and Development Board, Syracuse, New York.

84. Palermo, M.R., 1988, New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; Report 10 Evaluation of Dredging and Dredging Control Technologies, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

85. Pastorok, R.A., Lorenzen, M.W., Gina, T.C., 1982, Environmental Aspects of Artificial Aeration and Oxygen of Reservoirs: A Review of Theory, Techniques, and Experiences," Tech. Report E-82-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

86. Peterson, S.A., Sanville, W.D., Stay, F.S., and Powers, C.F., 1976, Laboratory Evaluation of Nutrient Inactivation Compounds for Lake Restoration, J. Wat. Poll. Cont. Fed. 48: 817-831.

87. Peterson, S.A., Sanville, W.D., Stay, F.S., and Powers, C.F., 1974, Nutrient Inactivation As a Lake Restoration Procedure - Laboratory Investigations. EPA 660/3-74-032.

88. Prepas, E.E., and S. Babin, Amish Lake Oxygen Injection Final Report (Year Two) 1989-90, National Water Research Institute, March 1990.

89. Rowell, H.C., 1990, Sediment Data From Onondaga Lake, SUNY College of Environmental Science and Forestry, Syracuse, New York.

90. Seppanen, P., 1974, Lake Aeration in Finland, Presented at the Conference on Lake Protection and Management, Madison, Wisconsin.

91. Sloan, R.J., Skinner, L.C., Horn, E.G., and Karcher, 1987, An Overview of Mercury Contamination in the Fish of Onondaga Lake, New York State Department of Environmental Conservation.

92. Smith, S.A., Knauer, D.R., and Wirth, T.L., 1975, Aeration As a Lake Management Technique, Technical Bulletin 87, Wisconsin Department of Natural Resources, Madison, Wisconsin.

93. Sonzogni, W., Richardson, P., and Monteith, T., 1983, Chloride Pollution of the Great Lakes, Journal WPCF, Volume 55, No. 5, p. 513-521.

94. Spagnoli, J. and Skinner, L., 1977, PCB's in Fish from Selected Waters of New York State, Volume 11, No. 2, Pesticides Monitoring Journal, p. 69-87.

95. Speece, R.E., Rayyan, F., and Givler, A., 1975, Invited Discussion of Ten Years Experience on Reservoir Aeration by H. Bernhardt (1974), Progress in Water Technology, Journal of International Association of Water Pollution Research, 7(314): 483-496.

96. Speece, R.E., 1975, Oxygen Restoration to Waters Released from Clarks Hill Reservoir, as Reported in Richard B. Russell Dam and Lake Design Memorandum No. 3, General Design Memorandum, Supplement No. 2, Prepared for U.S. Army Engineer District, Savannah, Georgia.

97. Speece, R.E., 1973, Alternatives Considerations in the Oxygenation of Reservoir Discharges and Rivers, Applications of Commercial Oxygen to Water and Wastewater Systems, R.E., Ed., University of Texas, Austin, Texas.

98. Speece, R.E., 1971, Hypolimnion Aeration, Journal of American Water Works Association, 64(1): 6-9.

99. Speece, R.E., 1970, Downflow Bubble Contact Aeration Apparatus and Method, U.S. Patent No. 3,643,403.

100. Stearns and Wheler, Projected Flows and Loadings, Metro Engineering Alternatives, Final Report, 1991.

101. Stearns and Wheler, Performance Characteristics Nitrogen Removal Alternatives, Task Report No. 6, October 1990.

102. Stearns and Wheler, Effluent Discharge Alternatives, METRO Syracuse STP, Task Report No. 8, November 1990.

103. Stearns and Wheler, 1990, Onondaga Lake Monitoring Program 1989, Appendix B.

104. Stearns and Wheler, 1990, Onondaga Lake Monitoring Program, 1989, Tables and Graphs.

105. Stearns and Wheler, Performance Characteristics Phosphorus Removal Alternatives, Task Report No. 3, September 1990.

106. Stearns and Wheler, Ley Creek STP Reconstruction, Task Report No. 4, Memorandum, September 1990.

107. Stearns and Wheler, Extraneous Flow Abatement, METRO Syracuse STP, Task Report No. 2, July 1990, Memorandum.

108. Stearns and Wheler, 1989, Onondaga Lake Monitoring Program Annual Report - 1987, Appendix B.

109. Stearns and Wheler, 1989, Comprehensive Performance Evaluation for Metropolitan Syracuse Sewage Treatment Plant, Final Plant.

110. Stearns and Wheler, 1981, Onondaga Lake Monitoring Program, 1980.

111. Stearns and Wheler, 1979, Onondaga Lake Storms Impact Study.

112. Stwart, K.M., 1979, Book Review of: Lakes of New York State, American Scientist, 67:480.

113. Sturgis, T.C. and Gunnison, D., 1988, New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; Report 6 Laboratory Testing for Subaqueous Capping. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

114. Tetra Tech, 1977, A Guide to Aeration/Circulation Techniques for Lake Management, EPA 600-3-77-004, p. 125.

115. UFI, 1990, Onondaga Lake Data and Modeling Effort.

116. U.S. Environmental Protection Agency, 1985, Remedial Action at Waste Disposal Sites (Revised), EPA/625/6-85/006, U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio.

117. U.S. Environmental Protection Agency, 1974, Urban Stormwater Management and Technology: An Assessment, National Environmental Research Center, Office of Research and Development, Cincinnati, Ohio.

118. Vollenweider, R.A., 1975, Input-output Models with Special Refernece to the Phosphorus Loading Concept in Limnology, Scheiz, Z. Hydrol., V.37, No.1, p. 53-84.

119. Walker, W.W., Review of Onondaga Lake Water Quality Data Base, Technical Assistance Proposal, 1990.

120. Wodka, M., Effler, S., and Driscoll, C., 1985, Phosphorus Deposition from the Epilimnion of Onondaga Lake, Limnol-Oceanagr., p. 833-843.

121. Yin, C. and Johnson, D.L., 1984, An Individual Particle Analysis and Particle Analysis Budget Study of Onondaga Lake Sediments, Upstate Freshwater Institute, No. 19.

122. Young, T.C., DePinto, J.V., and Seger, E.S., 1982, Transport and Fate of Heavy Metals in Onondaga Lake, New York, Bulletin Environmental Contam. Toxicol. 29, p. 554-561.

ANNEX B

Onondaga Lake
New York

Economics
Annex

1. Introduction 1

2. The Study Area 2
2.1. Location and General Description 2
2.2. Physical Characteristics 4
2.2.1. Vegetation 4
2.2.2. Water Quality 4
2.2.3. Wildlife 4
2.2.4. Recreational Resources 4
2.3. Land Use 5
2.3.1. Urban Land Use 8
2.3.2. Rural 9
2.3.3. Agricultural 9
2.3.4. Industrial/Commercial 9
2.3.5. Recreational 10
2.4. Available Services 11
2.4.1. Transportation Access 11
2.4.2. Water Supply 12
2.4.3. Sanitary Sewer Service 12
2.4.4. Utilities 12
2.4.5. Police And Fire 12
2.5. Demographics 12
2.5.1. Historical Population 12
2.5.2. Population Forecasts 14
2.6. Employment 14
2.7. Income 17
2.8. Housing Market 19
2.9. Recreation, Open Space And Parklands 19
2.9.1. Marina Uses 20

3. Revitalization Around Onondaga Lake 21
3.1. Development Goals And Policies 21
3.1.1. Major Underpinnings 21
3.1.2. Onondaga Lake Master Plan 22
3.1.3. Related Studies 22
3.1.4. Development Goals 22
3.1.5. Assumptions 24
3.2. Major Area Wide Projects 24
3.2.1. Carousel Regional Shopping Center 24
3.2.2. Franklin Square Office Renovation 25
3.2.3. Syracuse Harbor 25
3.2.3.1. Marina. 30
3.2.3.2. Restaurant And Retail Pavilion. 30
3.2.3.3. Residential. 30

3.2.3.4. Harbor Park. 30
3.2.3.5. Harbor Costs and Revenues. 31
3.2.4. Bikeway 31
3.2.5. Summary 33

4. Beneficiaries 34
4.1. Introduction 34
4.2. Future Development 34
4.3. Alternative Plans 34
4.4. Perceptions of Users 34
4.5. Recreation 35
4.5.1. Water Dependent Activities 35
4.5.1.1. Boating. 35
4.5.1.2. Swimming and Other Water Contact Sports. 36
4.5.1.3. Fishing. 36
4.5.2. Water Related Activities 36
4.6. Land Value 36
4.6.1. Commercial 37
4.6.2. Public 37
4.6.3. Residential 37
4.7. Commercial Tour Boat and Charter Benefits 37
4.8. Cost Reduction Benefits 37

5. Evaluation Methodologies 39
5.1. Value of Recreation 39
5.2. Contingent Valuation Method (CVM) 40
5.2.1. CVM Overview 40
5.2.2. CVM Concerns 41
5.2.3. Willingness to Pay versus Willingness to Accept (WTA) 43
5.2.4. Summary 44
5.3. The Travel Cost Method (TCM) 45
5.3.1. TCM Overview 45
5.3.2. TCM Concerns 46
5.4. The Hedonic Method 48
5.4.1. HM Overview 48
5.5. Recommendations of Valuation Methods Applied to Water Quality Improvements on Ononondaga Lake 48

1. Introduction

This section provides information about Onondaga Lake from an economic perspective. It provides an economic baseline of the study area and an overview of the goals, policies and strategies for future development on and around Onondaga Lake. Onondaga Lake has become the focus for plans future development. Many of the plans are predicated on the assumption that the Lake will undergo some level of cleanup before the development plans come into fruition.

Recreation is the primary thrust for future developmental plans around Onondaga Lake. Plans for the Lake once again center around the recreational needs of the area and the great potential Lake Onondaga possesses in fulfilling those needs. Also future development plans de-emphasize the industrial uses of the Lake which in the past included its intensive use as a site for dumping wastes. Planning is currently underway for reversing the negative impacts of historic dumping practices.

This section provides a preliminary review of the proposed plans of improvement with respect to what benefit categories would accrue from alternative proposals. It does not provide any quantification of economic impacts realized as a result of the implementation of the proposed plans. Benefits from the proposed plans of improvement would be realized in the form of national economic development (NED) and regional economic development (RED) impacts from each proposed alternative or combination of alternatives.

This section also provides a description of the economic evaluation techniques used to quantify benefits for water quality improvement projects. In addition a critique of the various methods is included outlining the advantages and disadvantages of each method with some examples of their use in previous studies.

2. The Study Area

This subsection addresses study area geographical location and area land use, physical characteristics of Onondaga Lake; and available public services.

2.1. Location and General Description

Onondaga Lake is located in Onondaga County in central New York State. The Lake is north west of the City of Syracuse. Syracuse is about 125 miles north west of Albany and 75 miles east of Rochester. (Figure 1).

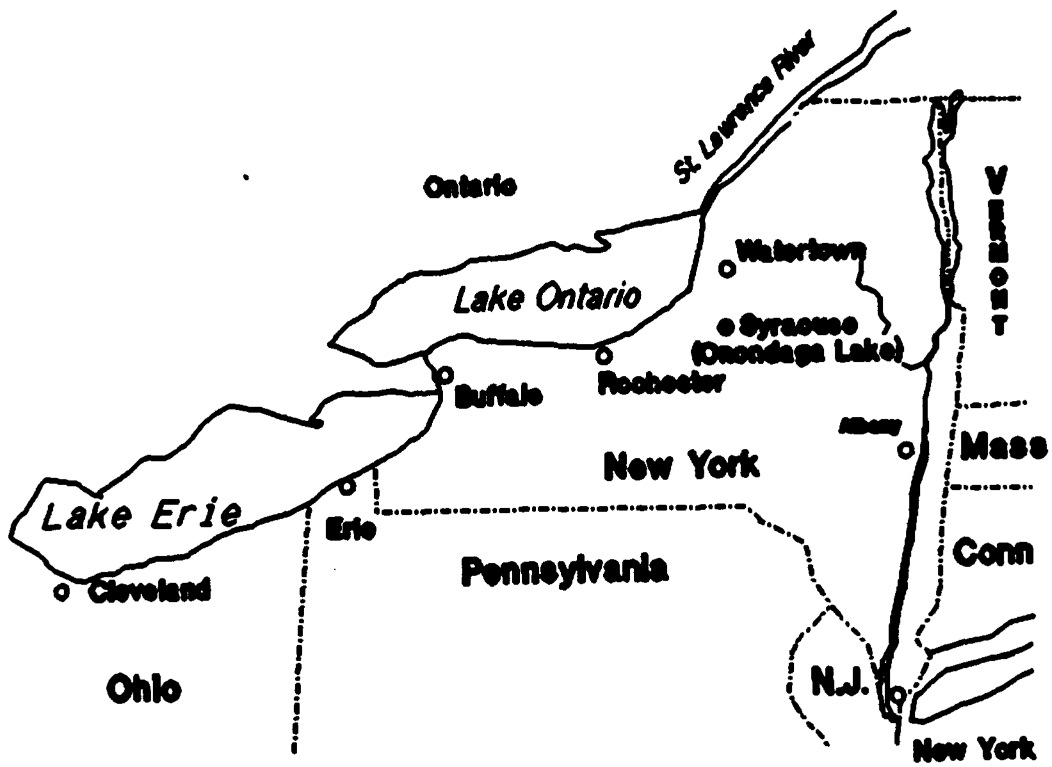


Figure 1 - Regional Location Map

The Lake surface area is approximately 4.5 square miles (approximately 4.5 miles long and up to a mile wide) and has a maximum depth of sixty-five feet. Major tributaries and their percentage inflows to Onondaga Lake are: Nine Mile Creek (38

percent), Onondaga Creek (34 percent), Metro Sewage treatment plant (17 percent), Ley Creek (8 percent) and Harbor Brook (3 percent).

The Onondaga Lake shoreline is approximately 12.2 miles long. About 9.5 miles, or 78 percent, is publicly owned. Onondaga County is the primary riparian landowner and a small amount of shroeland is owned by the City of Syracuse. The county owned property is primarily parkland located along the northwest, north and northeast perimeter of the lake. Existing County development includes a hiking/biking path which is planned to encircle the lake; an 80 slip marina with small boat launch ramp; a salt manufacturing museum; picnic areas; playgrounds; and sport playing fields. The city owned property is primarily focused in commercial and industrial developments. Mixed development is occurring on city land located along the southwest, south and southeast perimeter of the lake. About 2.7 miles of shoreline (22 percent) is in private ownership, primarily owned by Conrail, Allied Signal Corporation, Crucible Steel, and Niagara Mohawk Power Corporation. This land is located along the southeast, south and southwest perimeter of the lake. The state fairgrounds is also located in this vicinity.

The Lake has a total drainage area of 245 square miles. Current land use within the water shed is approximately 33 percent cropland, 28 percent urban, 22 percent woodland and 17 percent open and special uses. Onondaga Lake is located within the Oswego River Drainage Basin, which is a Lake Ontario tributary. The waters from Onondaga Lake flow northwesterly into the Seneca River (part of the New York Barge Canal System), then flow east and north into the Oswego River and then into Lake Ontario.

Several redevelopment projects are underway in the Onondaga Lake vicinity. On the south end of the lake, the Carousel Mall was completed in the fall of 1990. Other mixed developments, primarily commercial, residential and recreational are being considered to replace non-operational oil storage facilities and a warehouse terminal formally used by the NYS Department of Transportation for Canal maintenance purposes. Residential and commercial redevelopment of Franklin Square, an old warehouse district, is underway. The St. Marie De Gannentaha Living History site, formally the site of a 1656 era French Jesuit mission and fort, on the northwestern shore of Onondaga Lake is undergoing renovation.

Other potential developments include: a beach development, an expanded marina, a new launch site, an aquarium, restaurant/ dining area, visitors center, performing arts center, theme park, and Oil City Marina.

2.2. Physical Characteristics

2.2.1. Vegetation The type of vegetation along the lakes peripheral riparian shoreline and its major tributaries was documented during a field trip by Buffalo District personnel in May 1989. The area vegetation is predominately composed of woody and herbaceous vegetation.

2.2.2. Water Quality Onondaga Lake is an urban lake surrounded by commercial, industrial, and residential land use. The lake shoreline is the northern boundary of the city of Syracuse, and shoreline is also located in the towns of Geddes and Salina in Onondaga County. The villages of Liverpool and Solvay are located within these towns. Historically, the lake has served as a water supply and later as a receptacle for waste discharges for municipalities and industries. As a result the water quality has deteriorated significantly. The discharges of municipal sewage effluent and industrial waste discharges have left the lake polluted and hypereutrophic. Based on best use, the current New York State water quality classification for various sections of Onondaga Lake range from Class "B" to Class "C". Class "B" implies suitability for bathing and any other uses except as a source of water supply for drinking, culinary or food processing purposes. Class "C" implies suitability for fishing and any other use except for bathing, as a source of water supply for drinking, culinary, or food processing purposes.

Lake swimming was banned around the year 1940. Consumption of fish from the lake was also not recommended at this time. Although various measures have been taken over the years to improve water quality, and to some extent sediment quality, fishing is restricted to catch and release only status.

2.2.3. Wildlife Although the general land use pattern in the vicinity of the Onondaga Lake and its main tributaries is predominantly developed (industrial, commercial and residential) , a variety of wildlife inhabits the vegetated areas near the lake and along its tributary streams. Game and non-game species of birds, mammals, amphibians, and reptiles utilize the open land, woodland, idle land, urban parkland, and remaining wetland habitats in the vicinity of the lake and its waterways. Wildlife using the open land range from the cottontail rabbit to moles. Woodland wildlife species include the raccoon and thrush. Wildlife using the wetlands include herons, ducks, and geese. The open areas of Onondaga Lake are utilized by waterfowl (ducks, Canada Geese) as resting and feeding habitat - particularly during spring and fall migratory periods.

2.2.4. Recreational Resources A major portion of the 12.2 mile lake perimeter is comprised of parkland (Onondaga Lake Park) developed by Onondaga County.

The Onondaga Lake Park has an area of 1,040 acres with 41 acres of parking lots, 12 miles of road, and 34 buildings. Future plans for this park include the extension of the Onondaga Lake trail around the circumference of the Lake. The park provides a ballfield complex with 2,000 capacity bleachers, little league diamonds, soccer fields, picnic areas, six permanent comfort stations, a free jitney service, a concession building with snack bar and bicycle rental. Developments include the East Shore Trail: a 3 ¼ mile hikeway/bikeway (2 ¼ mile vehicle free), an 80 slip public marina with launch ramp, a salt manufacturing museum, newly renovated interpretive center, picnic areas, and playgrounds. The marina has been fully utilized for more than a decade. Onondaga County Parks maintains a waiting list of about 40 names of boat owners who desire a slip at the marina. The launch ramp offers an annual launch pass option ($60) or pay per launch ($5.00). In 1990, the launch generated revenues of $6,620. 1990 represents typical level of usage for the past several years.

Attendance at the Onondaga Lake Park exceeded one million visitors in 1990, approximately fifteen percent of whom attend special events. These special events include: professional world class lacrosse competition, annual national Thunderbolt hydroplane races, and the Intercollegiate Rowing Association regatta. Also the County Parks Department sponsors the annual Onondaga Lake "Waterfront Extravaganza" to promote the recreational resources of the Lake. The four day event has included nationally known musical groups and a Cypress Garden's style waterski show. The Lake Park was identified as the most popular park in Central New York in a poll conducted by a local Syracuse news paper last year of their readers.

Recent water quality tests (June 1990) performed by the Onondaga County Department of Health has confirmed the NYSDEC classifification of Onondaga Lake as Class B, approved for incidental water contact. The tests identified water clarity as the primary problem with the resultant rating. The Lake is regularly used by wind surfers and occasionally by water skiers, though swimming less common. Negative publicity through frequent news coverage instills continual cause for health concerns by potential Lake users.

2.3. Land Use

Syracuse, Onondaga County's largest city and county seat, is near the geographical center of the county. It is also at the center of the fastest growing urban system in New York State. It is an industrial, service, and distribution center, and a medical and educational center. The main industries are electronics, machine parts, chemicals, refrigeration, and air-conditioning equipment. Limestone and shale quarries and salt wells produce materials used mainly in the manufacture of chemicals and plaster; and road construction aggregate and maintenance.

Nearly 80% of all land parcels in Syracuse, are residential, and another 8% are vacant residential land. Figure 2 presents land use categories and the percentages of land use in the City of Syracuse. The trend in Syracuse indicates a continual slow decline in total residential units although new residential construction (both single family and apartments) continues throughout the city. Recent housing development has occurred in the Economic Development Zone, Armory Square, and Franklin Square. Manufacturing has declined in recent years while office ,institutional, and government uses have increased. Retail uses have generally declined although the redevelopment of the Oil City area of Syracuse, including the completion of Carousel Center (shopping mall), is reversing this trend. Office rehabilitation is taking place in the Armory Square, Marshall Street, and Franklin Square areas. The downtown area struggles to retain retail activities while cultural, government, and office uses continue to do well.

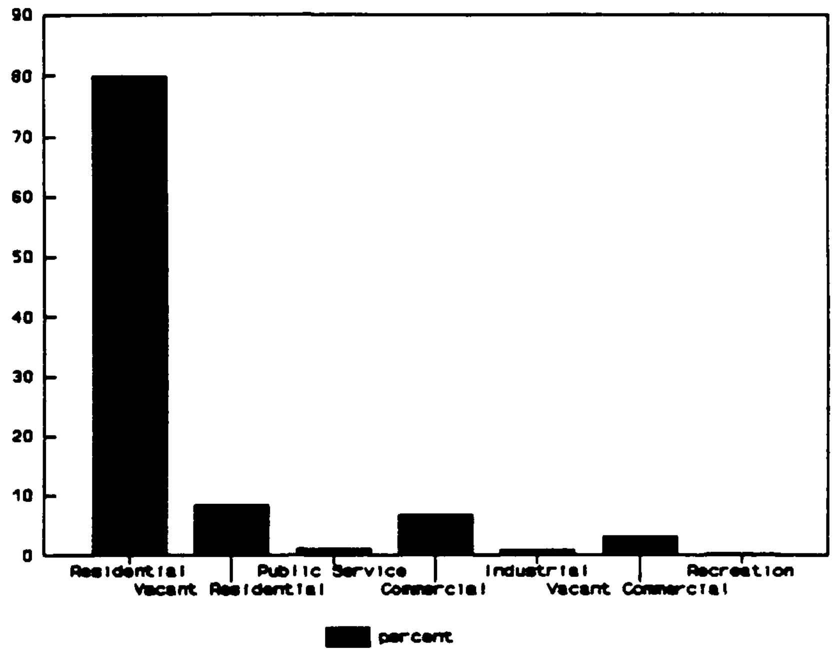


Figure 2 - Land Use City of Syracuse (1989)

Agricultural products from farms consist mainly of milk. Other products of importance are dairy cattle and calves, poultry and poultry products, fruits, berries, vegetables, and grains. Much of the milk and most of the other products are consumed within the county.

Land use development has followed a pattern of decentralization that has existed for the past several decades, leading to expansion in the suburban towns and a mixed pattern of stability, decline, and redevelopment in Syracuse.

Changes in land use categories within Onondaga County varies from area to area. The northern towns of Onondaga County have had the greatest change with the eastern and western towns having considerably less; the southern towns have had relatively little development. The variability has been due to the availability of

infrastructure, easily developable land, public attitudes, and developer initiative.

2.3.1. Urban Land Use Onondaga County is divided into two principle areas, lands contained within the Consolidated Sanitary District and those lands outside the District. The Consolidated Sanitary District is comprised of urban lands that is supported by a municipal infrastructure. Figure 3 shows the boundaries of the Consolidated Sanitary District within Onondaga County.

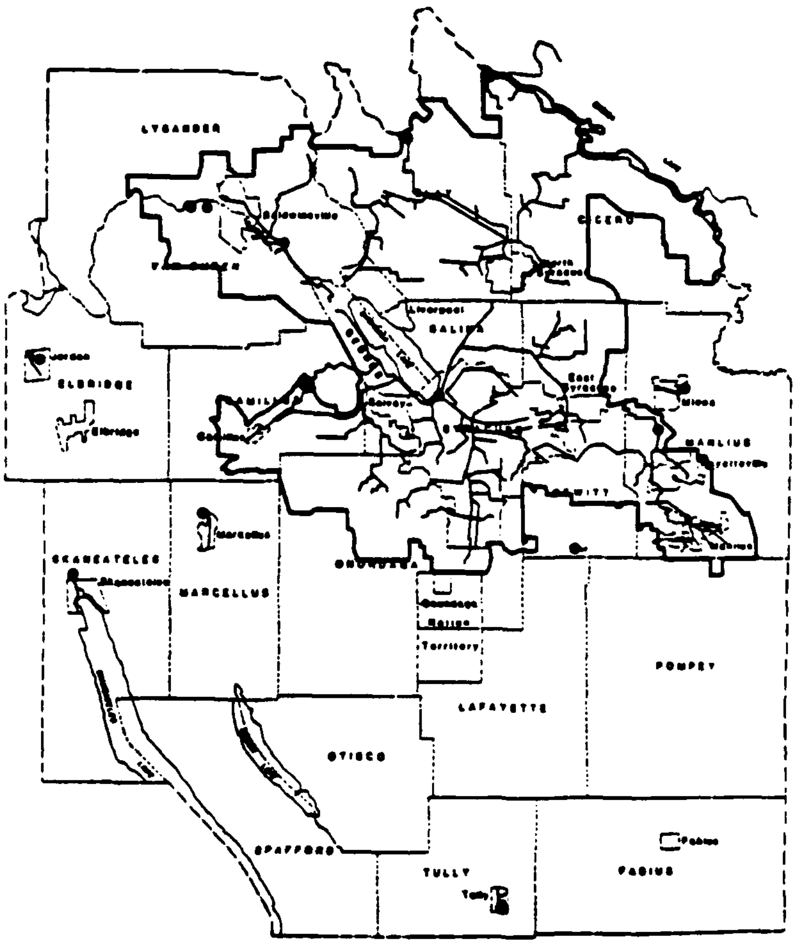


Figure 3 - Consolidated Sanitary District - Onondaga County

Figure 4 presents the suburban land use of Onondaga County within the County's Consolidated Sanitary District. Suburban building trends include strong residential construction, particularly single family units, which continue to be the dominant use for the next two decades, but growing at a slower pace. Commercial land use has expanded in the suburbs for retail, office, and service activities. In retailing, new malls have been built (Carousel Center, Great Northern and Kimbrook Village Square); existing malls have been expanded (Camillus, Penn Can, Shoppingtown, Fayetteville) and retail strips have expanded (Route 11, Route 57, Route 31). Office parks have been expanded where there is good access to the interstate road network. The expansion of service activities has been scattered, but near retail development. Moderate growth of industrial parks has been counterbalanced by the closing of several large manufacturing companies. The trend in manufacturing is for little growth or some decline. Distribution, trucking, and warehouse activities should continue to remain strong. Agricultural land use will decrease within the suburban area as residential development continues and as land costs and taxes make it desirable to convert land to urban uses.

2.3.2. Rural Figure 5 presents the rural land use pattern of Onondaga County outside the County's Consolidated Sanitary District.

2.3.3. Agricultural Agriculture remains an important component of Onondaga County's economy. The number of farms is still significant (772 in 1987, down from 835 in 1982) and the acreage involved in farming (158,276 in 1987, down from 179,015 in 1982) represents nearly 34% of the land area of the County. The market value of agricultural goods increased modestly from $52,221,000 in 1982 to $53,834,000 in 1987. The future projection for the agricultural sector is continued decline in acreage and number of farms but a continued influence on the county's land use.

Agricultural activity predominates in areas not serviced with public sewer and water. However, agricultural areas within the Consolidated Sanitary District will be under the most pressure to be converted to other land uses.

2.3.4. Industrial/Commercial Land suitable for development for commercial and industrial use is available in numerous locations throughout the County, particularly in the City of Syracuse and in suburban areas. From the Onondaga County "2010 Development Guide", potential economic development areas have been identified. The potential areas shown within the County Sanitary District consist of organized industrial parks, areas appropriate for development because of their location, zoning, infrastructure, and former industrial sites. indicates the Potential Economic Development Areas.

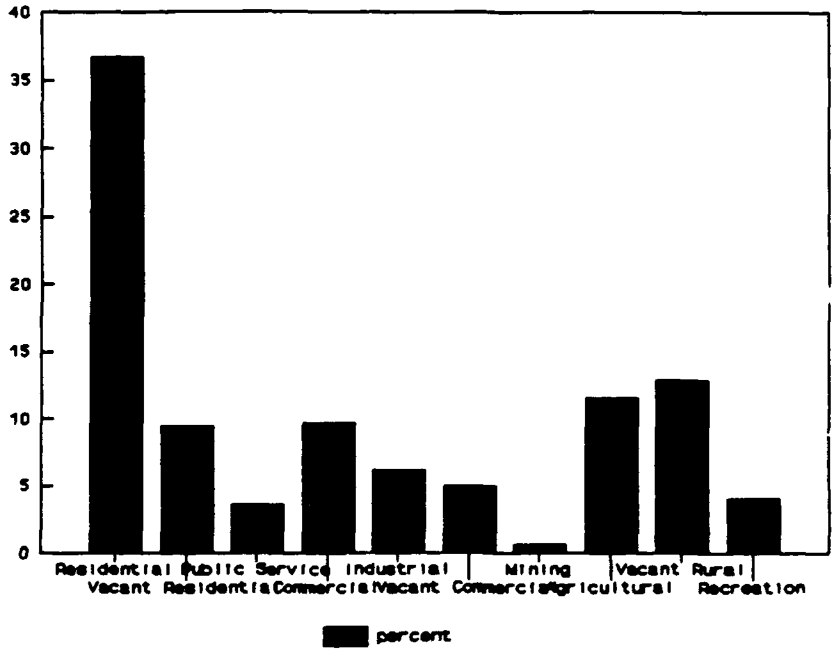


Figure 4 - Suburban Land Use within the Onondaga County Consolidated Sanitary District - 1989.

<u>2.3.5. Recreational</u> The Onondaga County Department of Parks and Recreation has fifteen facilities that it administers with a total of 5,857 acres, 65 miles of roads, 58 miles of trails, and 121 buildings. County Parks include a zoo, museums, beaches, picnic facilities, conference centers, ball fields, a cemetery, a fish hatchery, unique natural areas, and open space as well as administrative and maintenance facilities.

The County administers the Onondaga Lake Park at the northern and eastern sides of Onondaga Lake.

The demand for recreational development of the Lake is strong since the lake is located at the northern boundary of the City of Syracuse, a significant urban area of central New York State. The New York State Comprehensive Recreation Plan, dated

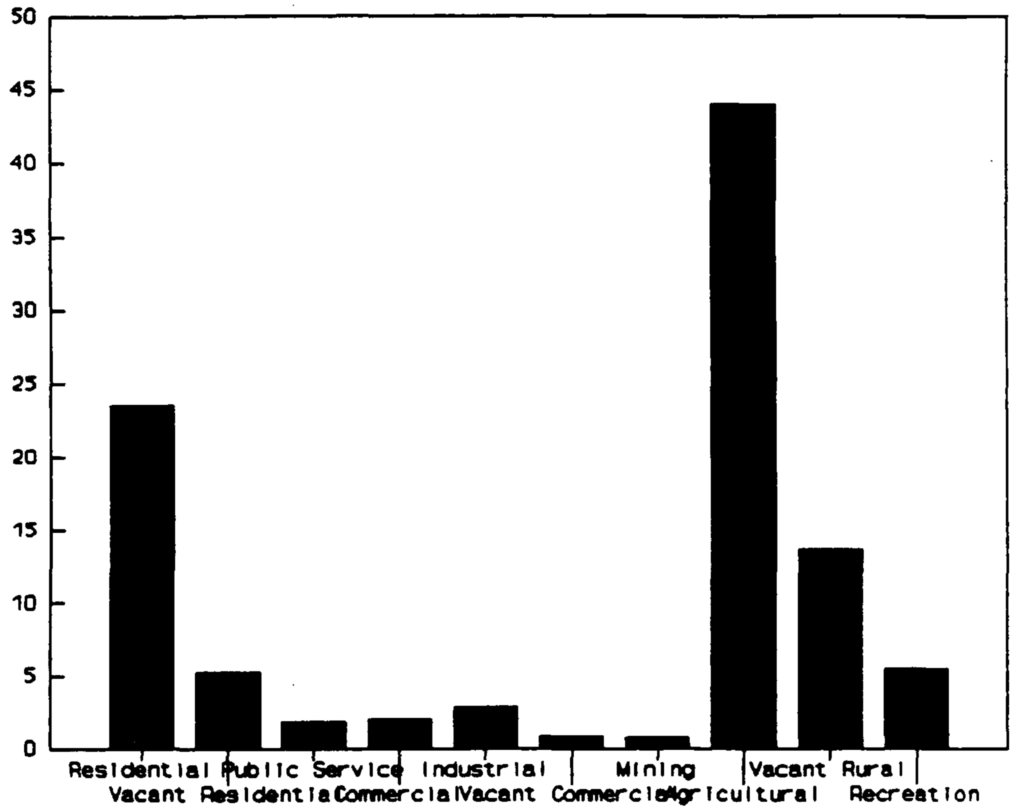


Figure 5 - Rural Land Use outside of the Onondaga County Consolidated Sanitary District - 1989.

1983, identifies a number of activities as high regional demand activities for which facilities development is of high demand. Activities include: swimming, boating, picnicking, hiking/biking and tennis. The potential for development of these facilities around Onondaga Lake to meet these demands is high, particularly if the water quality problems are alleviated.

2.4. Available Services

2.4.1. Transportation Access The City of Syracuse is a major transportation hub in central New York State. Two major interstate highways intersect at Syracuse, the Thruway (US 90) providing east-west access and US 81 providing north-south access. Interstates 690 and 481 provide additional bypass access in the Syracuse area.

Both Conrail and Amtrack have major rail service to the Syracuse area. Hancock International Airport located just north of Syracuse is serviced by ten major airlines. The bus terminal in Syracuse is serviced by two interstate bus companies and three regional bus companies. Onondaga Lake is a branch from the Seneca River Barge Canal portion of the New York State Barge Canal system to Syracuse. The system now services primarily recreational vessels. A maintenance office and terminal is still located at the southeastern end of the lake along Onondaga Creek.

2.4.2. Water Supply Communities in the project vicinity generally obtain their community water supplies through the Onondaga County Water Authority. They in turn obtain their water supply from the Metropolitan Water Board. The primary source of water is Lake Ontario. Supplemental sources of water include: Otisco Lake, Skaneateles Lake and Ray Dam.

2.4.3. Sanitary Sewer Service A number of towns and cities discharge their effluent into Onondaga Lake. The largest metropolitan plant is the Syracuse Metro Sewage Treatment Plant. This plant is now a tertiary treatment plant with a design flow of about 80 million gallons per day. A number of villages discharge their effluent into tributaries of Onondaga Lake. Ninemile Creek receives discharges from the village of Marcelles as well as discharges from wastebeds of Allied chemical operations. In addition, 53 combined sewer overflows discharge into Onondaga Creek. Two combined sewer overflows enter Ley Creek, as do the sewer overflows at the Brooklawn and Ley Creek pump stations. Harbor Brook receives discharges from 20 combined sewer overflows of the Hillcrest and Brookside pumping stations. Tributary 5a receives treated wastewater from Crucible Steel.

2.4.4. Utilities The project area is located in close proximity to the city of Syracuse and access to such utility services as water, sewerage, gas, electric and telephone are readily available.

2.4.5. Police And Fire Local villages, towns and cities provide police and fire protection and police services. Police services are supplemented by the county sheriffs department and New York State Police.

2.5. Demographics

2.5.1. Historical Population Preliminary 1990 census counts indicate Onondaga County's population at 469,000. The City of Syracuse, located adjacent to Onondaga Lake, is the third largest city in Upstate New York with a population near 164,000. Onondaga Lake and a majority of the Onondaga Lake watershed is contained within Onondaga County. The watershed has a population of approximately

500,000. Table 1 presents historical population data from 1930 to 1990 for Onondaga County, Syracuse, and "All Other" county towns.

As a result of the post World War II economic boom, the County's population grew through 1970 to about 473,000. It then declined slightly through the 70's and 80's. Moreover a significant redistribution of population has occurred within the County since 1960. Population has shifted in the County to the outer suburban areas from the City and inner suburbs. The City represented 51 percent of the County's population in 1960, decreasing to 35 percent by 1990. Towns surrounding the City including Camillus, DeWitt, Salina and Geddes have experienced a population decline. Net population loss from outmigration, was 35,000 in the 1970's and 29,000 in the 1980's. Population losses have been primarily attributed to the outmigration of the very mobile age 20 to 34 group. As this baby boom generation ages they will be less mobile and therefore positive slow growth can be expected.

Table 1. Historical and Projected Population

Year		Onondaga County	Syracuse	Towns
1930		291,606	209,326	82,280
1940		295,108	205,967	89,141
1950		341,719	220,583	121,136
1960		423,028	216,038	206,990
1970		472,835	197,297	275,538
1980		463,920	170,105	293,815
1990	1/	468,973	163,860	305,113
1995	2/	469,142	160,300	308,842
2000	2/	473,814	159,300	314,514
2005	2/	478,378	159,100	319,278
2010	2/	482,729	158,950	323,779

1/ Source: CENDATA, Bureau of Census, U.S. Department of Commerce.
2/ Source: NYS Department of Economic Development, 1985.

Employment opportunities and age distribution are major factors influencing migration choices. Cultural and social attitudes, housing costs, the ability of other areas to accept growth, and a host of national and state policies affect Onondaga County's ability to retain population and thus the likelihood of population growth in the future.

2.5.2. Population Forecasts. Table 1 presents population forecasts for Onondaga county, the city of Syracuse and "All Other" county towns. Slow future growth is expected for several decades returning to 1970 population levels by about the year 2000. Of the three factors affecting population growth; birth rates, death rates and migration rates, migration is the only factor which may change markedly in the future. Birth and death rates have been relatively stable over the last decade and should remain stable in the future. According to the NYS Department of Economic Development outmigration is projected to decline. Projections assume that as the rate of outmigration decreases, the County's population will increase through 2010. New commercial, retail, residential, and recreational development currently planned around the perimeter of Onondaga Lake is anticipated to become a contributing factor to the attraction of future population.

In the next ten years those in the 20 to 34 year age group will decline by 20 percent while those 35 to 44 years of age will increase 14 percent. The 45 to 65 age group will rise by 19 percent. Between 2000 and 2010 the trend of an aging population continues as the 35 to 44 age group decreases 18 percent and the 45 to 64 age group increases by 26 percent. Between now and 2010 the age group 65 and older is expected to increase 14 percent.

2.6. Employment

Table 2 presents data on the number of business establishments in 1987 in the State, The Syracuse MSA and Onondaga County.

Table 2. Business Establishments, 1989.

Business Establishments	STATE NYS	%	MSA Syracuse	%	County Onondaga	%
Total	462,048	100%	13,777	100%	10,735	100%
Manufacturing	28,931	6%	768	6%	572	6%
Construction	44,836	10%	1,808	13%	1,355	12%
Trans, Public Util	61,917	13%	1,519	11%	1,190	11%
Finance, Insurance, Wholesale, Retail	147,550	32%	4,797	35%	3,708	35%
Services	163,652	35%	4,520	33%	3,647	34%

Source: New York State Business Fact Book, 1990. NYS Department Of Economic Development

Table 3 presents historical data (1986) on employment in Onondaga County and the Syracuse Labor Area. The leading employment sectors in the Syracuse and Onondaga County vicinity include: Services (27%-28%); Manufacturing (23%-22%); Retail (21%-20%); Finance, Insurance, Real estate (8%-9%) and Wholesale (8%).

Table 4 presents employment projections for the Syracuse MSA. Employment growth for all sectors combined is about .3 percent per year. The fastest growing sectors are Construction (.67% per year); Wholesale (.64% per year); Services (.54% per year); Real Estate (.49% per year); Transportation, Public Utilities, finance and Insurance(.44% per year) and Retail (.23% per year.) Manufacturing growth is almost non existent.

Table 3. Employment, 1988 (Covered by Unemployment Insurance).

Type Of Business Establishment	STATE NYS	%	MSA Syracuse	%	County Onondaga	%
Total	6,701,628	100%	247,041	100%	209,623	100%
Manufacturing	1,214,546	18%	53,418	22%	42,994	21%
Construction	337,044	5%	14,517	6%	12,117	6%
Wholesale	481,990	7%	18,127	7%	16,491	8%
Retail	1,236,818	18%	52,855	21%	42,670	20%
Services	2,172,453	32%	68,158	28%	60,130	29%
Trans, Public Util	401,878	6%	17,793	7%	14,993	7%
Finance, Ins, Real Estate	791,491	12%	20,017	8%	18,804	9%
Other	65,408	1%	2,156	1%	1,423	1%

Source: New York State Business Fact Book, 1990. NYS Department Of Economic Development.

Table 4. Syracuse MSA Employment Projections: 1995-2015.

Type Of Business Establishment	Syracuse MSA 1995	2000	2005	2015
Total	362,000	376,600	384,700	386,000
Manufacturing	67,900	68,900	68,300	68,200
Construction	25,800	27,600	28,700	29,500
Wholesale	23,600	24,800	25,900	26,800
Retail	55,100	57,200	58,100	57,700
Services	86,500	91,900	94,600	96,400
Trans, Public Util	19,600	20,500	21,200	21,400
Finance, Ins, Real Estate	26,300	27,800	28,700	29,000

Source: 1985 OBERS BEA Regional Projections: Volume 2, Metropolitan Statistical Area Projections To 2035. 1985.

The labor force is expected to grow at a slower pace than past years due to fewer new entrants in the labor market. The number of younger workers is expected to decline

and participation rates by women will likely level off. Unemployment will continue to be low, under a stable economy. Workers salaries and benefits will increase as competition for scarce workers takes place, particularly at the low end of the scale. Education and training of the work force will become increasingly important.

Regional destination retail will be extremely competitive due to the opening of the Carousel Mall. Any new regional retail on the lake will not be supportable. The office worker market will continue to be addressed via downtown retail, even though it is struggling. Halcyon Ltd concluded the concept of an outdoor festival market, with a limited outdoor season, was not encouraging based upon a similar development strategy in other small cities.

However, the demand for regional destination restaurants associated with the waterfront, did seem viable. Halcyon recommended a 3-5,000 square foot upscale restaurant a 10-12,000 square foot bar/restaurant/nightclub and a 3,000 square foot cafe, for the canal area. Retail uses should accommodate the on site market users including boaters and residents of any housing developed. The on site market users are projected to support a 2000 square foot grocery/deli and about 5,000 square feet of service convenience uses.

2.7. Income

Table 5 presents data on income in Onondaga County and the Syracuse MSA for 1986. Per capita income for the Syracuse MSA area was about $14,300 in 1986 dollars. Per capita income was slightly higher in Onondaga County for the same time period: $15,100.

Table 5. Personal Income, 1986.

	STATE NYS	MSA Syracuse	COUNTY Onondaga
Total Income	$301,769,500	$9,268,700	$ 7,007,000
Income Per Capita	$ 16,980	$ 14,275	$ 15,129

Source: New York State Business Fact Book, 1988.

The average annual rate of real income increase in Onondaga County was 2.5 percent between 1980 and 1985, and 4 percent between 1985 and 1986. This pattern reflected State wide increases except in 1985 when the State as a whole did better

than the county. Estimates of 1989 county average household income is $,32,487. This estimate is expected to grow by 1.3 percent per year, adjusted for inflation, until 1994 when it will reach $34,646.

Table 6 presents the leading income sectors in the Syracuse MSA. The leading sectors include: Manufacturing (28%), Services (19%), Transportation and Public Utilities (10%), Construction (9%), Wholesale (7%), Retail (7%), and Finance, Insurance, Real estate (6%).

Table 6. Projected Personal Income For The Syracuse MSA (1995-2015), ($millions)

Type Of Business Establishment	Syracuse MSA YEAR			
	1995	2000	2005	2015
Total	3,714.5	4,044.4	4,328.1	4,768.5
Manufacturing	1,053.1	1,135.8	1,213.4	1,340.2
Construction	325.0	353.1	375.3	407.1
Wholesale	278.4	304.8	331.8	372.1
Retail	238.0	259.6	275.5	298.7
Services	699.6	779.0	841.3	941.1
Trans,Public Util	351.5	391.7	426.6	477.6
Finance, Ins, Real Estate	238.0	259.6	275.5	298.7

Source: 1985 OBERS BEA Regional Projections: Volume 2. Metropolitan Statistical Area Projections To 2035, 1985.

Growth in personal income for all sectors (Table 6) combined is about 1.26 percent per year. The fastest growing sectors are: Transportation, Public Utilities, (1.54% per year); Services (1.49% per year); Wholesale (1.46% per year); Manufacturing(1.21% per year); Retail(1.14% per year); Finance, Insurance and Real Estate (1.14% per year) and Construction(1.13% Per year).

Economic indicators for Central New York are anticipated to show modest economic growth, assuming the absence of an economic recession caused by forces outside the local economy. The good infrastructure and quality, (though increasingly scarce) labor force and relatively low cost of living and low wage rates, all contribute to the

likelihood of this steady growth.

The service sector will continue to show growth, particularly in such sectors as financial and insurance. Manufacturing employment is expected to remain steady or may decline somewhat while maintaining production levels.

2.8. Housing Market

The number of single family housing units in Syracuse decreased slightly, while the number in the County outside the City increased by 40,000, between 1960 and 1990. Multifamily units in Syracuse during the same time period, increased by 5,000, while those outside the City increased by 19,000. However, new forms of housing including townhouses and condominiums have gained some acceptance in the market, especially in the last five years.

The housing market will be impacted by population trends. The change in population makeup will decrease demand for starter homes and increase demand for products geared to "empty nester" and elderly households. The "empty nesters" will need less square footage per housing unit but will be able to afford more amenities. Also the elderly will be interested in special services provided with housing.

A demand for 11,000 new housing units is projected for the next ten years, based on household formation. This is 31 percent less than the 16,000 new units which were built in Onondaga County between 1980 and 1990.

Over the same 10 year period, Halcyon Ltd. has estimated a need for 568 townhouse style housing units at the waterfront location. The waterfront area has plenty of land available for such development as well as the infrastructure to support that growth. Since waterfront sites are generally very competitive with other sites, a somewhat larger market share may be realistic.

2.9. Recreation, Open Space And Parklands

The demand for recreational development of the lake is particularly strong since the lake is located at the northern boundary of the city of Syracuse, a significant urban area of New York State. The New York State Comprehensive Recreation Plan (1983) identified recreation design day activity deficiencies in Onondaga County for the following activities from 1980 to the year 2000: swimming, boating, picnicking, hiking/biking and tennis. The projected design day deficiencies corresponds to a need for additional recreational facilities to meet this excess demand. The development of new recreational facilities around Onondaga Lake would help meet these excess

demands.

2.9.1. Marina Uses The market for marina related uses is quite good, given registration of pleasure craft in Central New York has risen by 15 percent annually between 1986 and 1988. Most existing marina facilities are fully rented, and some have long waiting lists.

If boat registrations grow by five percent per year, and the downtown waterfront area can capture 25 percent of this growth (this seems very reasonable since the lake is located adjacent to the highest concentration of population in the county), Halcyon Ltd. recommended a 150 slip facility be developed in the Canal Terminal area. Since the low rail bridge prevents this area from accommodating sail boats, there is a clear opportunity for sailing facilities elsewhere on the lake.

Also, the demand for a public launch facility seems very good, given the numbers of small boats registered in the area.

Likewise, the market for marina-associated services such as storage, repair, a ship's store and fuel is also projected to support a moderately sized facility of 1,500 square feet.

3. Revitalization Around Onondaga Lake

Over the last several years, there has been much interest in developing lands on and around Onondaga Lake. Local governments along with various interest groups recognizing the area's potential have joined in developing strategies in better utilizing the area which is rich in natural and historical resources.

3.1. Development Goals And Policies

The major planning framework for Onondaga County has been set out in a draft report of "Onondaga Counties Development Goals And Policies" completed in June 1990. This report outlines the future development, management and financing of land use in Onondaga County to the year 2010. Management policies were presented for community consideration and debate to facilitate developing a set of common goals and infrastructure management policies to achieve these goals. The report recognized the interrelationship between land development, public infrastructure, and fiscal capability. Also, the need for intergovernmental and private sector co-ordination in the promotion and management of land development and necessary infrastructure needs were recognized. In addition, effective county government management of the infrastructure system is needed to provide a co-ordinated response to future land use development initiatives.

3.1.1. Major Underpinnings Guidelines were developed as the basis for future development policy. These are as follows:

- All environmental, infrastructure and land development policies would be developed keeping in mind the effects on wastewater treatment drainage, highways, water supply, parks, land use planning and economic development.

- All fiscal policies and programs would be: sensitive to the natural environment, promote sound economic growth, promote an attractive community, be fiscally responsible and cost efficient in developing public infrastructure, and be coordinated among all the affected public and private entities.

- No approval for development of land under existing land use classifications, or revised land use classifications, would be approved unless they meet guidelines set by the Onondaga County departments of Transportation, Health, and Drainage and Sanitation. The plan itself would be reviewed at five year intervals by the Syracuse-Onondaga County Planning Agency.

3.1.2. Onondaga Lake Master Plan Development around Onondaga Lake will be directed according to a master plan currently being developed. (Figure 6) The Metropolitan Development Association, a consortium of local business and industrial leaders, has received a grant from the State of New York, Onondaga County and the City of Syracuse to prepare a masterplan intended to serve as a blueprint for land use in the areas directly adjacent to Onondaga Lake. The plan includes such areas currently under study as: the Syracuse Harbor, Onondaga Lake Bikeway, Tailings Pond, NYS Fairgrounds and the Onondaga Creekwalk feasibility Study. The plan also includes existing areas presently under construction such as: Convention Center, Armory Square, Franklin Square, Onondaga Creekwalk, Carousel Center Mall, CNY regional Farmers Market, Ste. Marie de Gannentaha Museum and the Salt Museum. The Master plan addresses a number of potential elements including an Amusement Park/Theme Park, Restaurants, Boat Rides/Dockage, Marina, Performing Arts Center, Swimming Beaches, Motorized Jitney Service along the Lake Shoreline, Wetlands/Wetlands Interpretive Center, Aquarium/Discovery Center, CNY Watersports Athletic Training and Testing Center, Hotel, Improved Traffic and Parking, Limit Access On Parkway, Additional Parklands, Improved Mass Transit, Residential, Light Industrial/Office Park, Additional Retail, Historical Interpretation-Cold Spring/Mud Lock Interpretive Center, Salt Museum Interpretive Center, and Historical Museum.

3.1.3. Related Studies The land use plan being developed is framed by current land use and ownership patterns, land classified as existing NYS DEC Federal Wetlands, as well as the more than 30 projects or studies currently affecting Onondaga Lake. Some of these studies include: upgrading the capacity and capability of two sewage pumping stations; modifications of the Metro Sewage Treatment Plant; Development of a Non-Point Phosphorous Loading Model For Onondaga Creek, an evaluation of the Onondaga Lake fishery and habitat, monitoring lake quality by Onondaga County and development of a Recreational Development Plan for the lake.

3.1.4. Development Goals A number of goals have already have been identified by the working subcommittees: the New York State Fairgrounds and the Inner Harbor should be the areas of intense activity, the shoreline of Onondaga Lake should remain in public ownership, the land uses around the lake should reflect the lake as a natural resource with the Onondaga Lake Master Development Plan proposing land uses which would provide educational opportunities about the lake and the cleanup processes, the lake should have a strong recreational focus, boating opportunities should exist for a variety of boat types, and year round recreational opportunities should be present.

A timeframe has been attached to a number of these goals. Master Plan Components

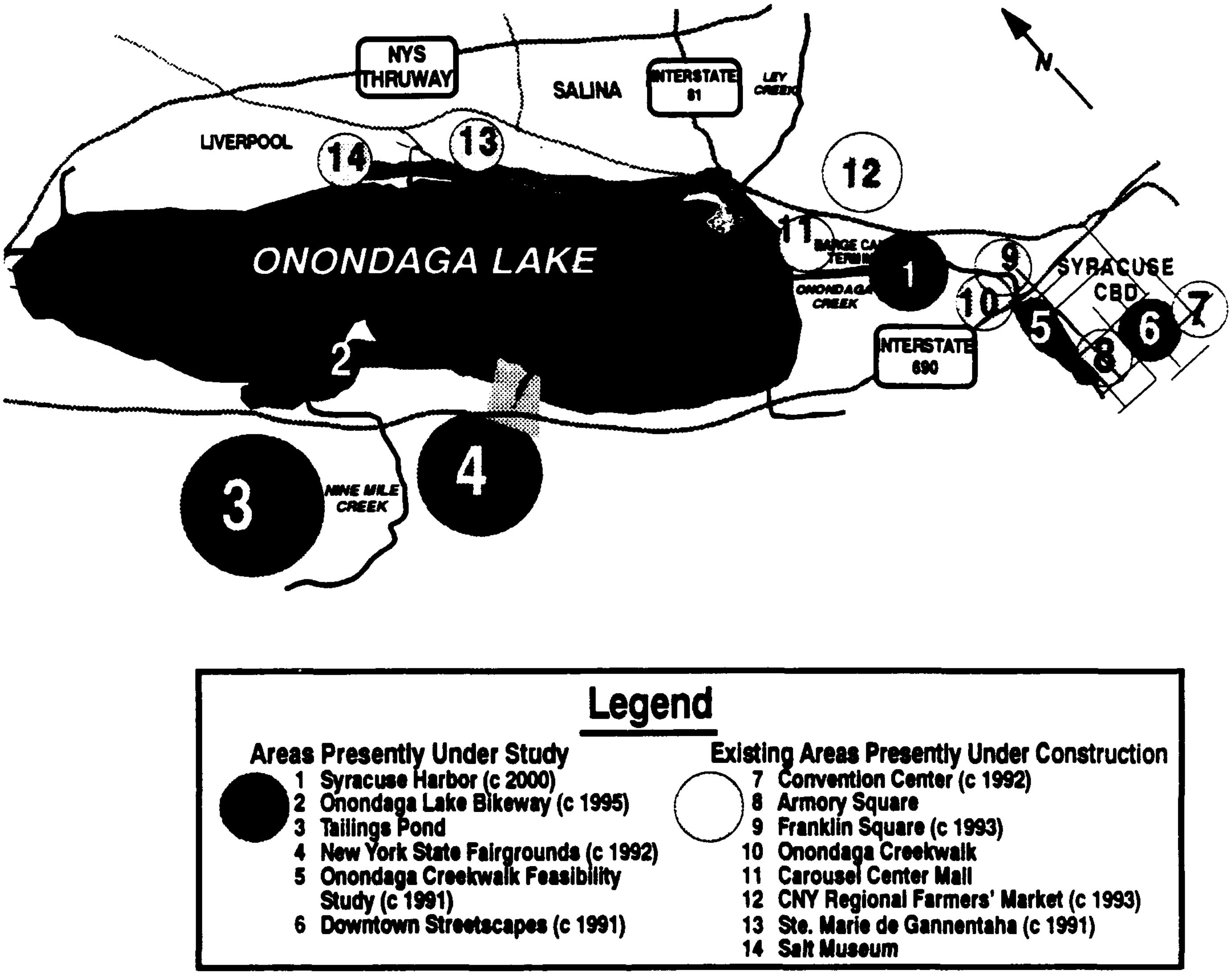


Figure 6 - Onondaga Lake Master Plan

that could be accomplished in a 10 to 15 year time frame were called near term goals. Some of these goals include: completion of the Onondaga Lake Bikeway (1995) and Onondaga Creek Walk from the Syracuse Inner Harbor to Armory square (1991); development of a lake water taxi with six to eight stops around the lake; reroute the Conrail Chicago mainline tracks to the west side of the State Fairgrounds; development of the Syracuse Inner Harbor (2000); water surface use zoning for the lake; expansion of the existing Liverpool marina; new marina facilities at the southeast and northwest corner of the lake; development of a Central New York Water Sports Training Center for crew, kayak, canoe, bicycle and cross country skiing teams; recreational vehicle camping facilities; development of a beach; expansion of the existing Salt Museum; relocation of Griffin Stadium facilities to Hopkins Road or the Allied waste beds; and development of a Wetlands Interpretive Center.

3.1.5. Assumptions Major assumptions needed for the above to become reality include: the availability of private monies to achieve the master plans goals, public support of the master plan and willingness to pay for the plan and implementation thereof, provision of adequate parking and access for all uses, a strategy for dealing with bacterial contamination of the lake will be available by 1992, and land development will proceed faster than the solving of water quality problems.

Other major assumptions made by the master plan were: the water quality in Onondaga Creek and Onondaga Lake will continue to improve, plan implementation will pose no significant and insurmountable threat to public health and safety from hazardous materials, the city can acquire the land surrounding the Harbor at no cost but would bear the cost of environmental remediation and consolidation of DOT uses, existing investments in Oil City (office space and housing in Franklin Square and the Carousel Center Regional Shopping Center) will generally be successful, Syracuse waterfront development will rely on regional market support, and Harbor development will result in a mix of uses and character that does not currently exist in the market place.

3.2. Major Area Wide Projects

Given the above two planning documents and the aim of making the Onondaga Lake/Syracuse area a major regional destination, a number of major projects have either been completed or are in advanced stages of development. Some of these projects are discussed below.

3.2.1. Carousel Regional Shopping Center The Pyramid Corporation has constructed one of the largest malls in central New york, just north of the city of Syracuse in an area known as Oil City. This mall opened in 1991 and, when fully

occupied, will have 1.4 million square feet of retail space featuring 125 stores, including eight anchors. The Mall not only serves as a regional retail center, attracting consumers to the area but also may serve as the catalyst for other development plans in the area.

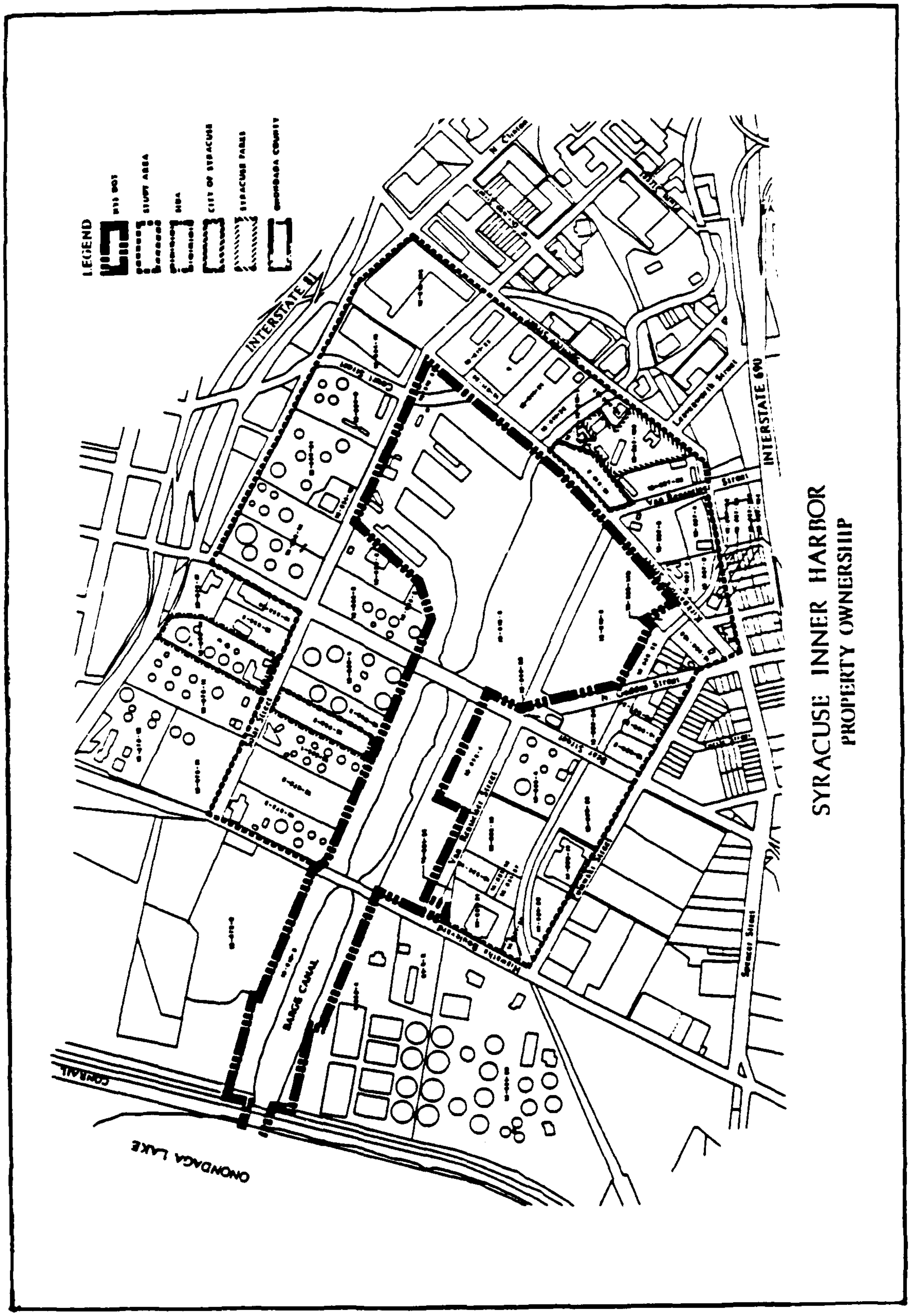
3.2.2. Franklin Square Office Renovation The Franklin Square area is located just south of the Special Inner Harbor area. Land use in the Franklin Square area is changing from old warehouse space to office/residential. A number of old brick warehouse buildings are undergoing renovation and conversion to office space. New multi-family housing is also being constructed in this area. Renovation costs for this area were $12.1 million in December 1990. The renovation is expected to be completed by 1993.

3.2.3. Syracuse Harbor A major project currently under study is the renovation of the Syracuse Harbor area. A project feasibility study entitled "Design And Land Use Feasibility Study, Barge Canal Harbor, Syracuse New York" was completed in June 1990 for the Syracuse Industrial Development Agency. The studies purpose was to evaluate the development potential and devise an appropriate redevelopment strategy for the Barge Canal Harbor in Syracuse New York.

The study area is a 127 acre parcel of land currently owned by the New York State Department of Transportation. The study area also includes 54.4 acres of water (Figure 7). The area is located in Oil City between downtown Syracuse and the shores of Onondaga Lake.

The plan is dependent upon a consolidation of New York State Department Of Transportation (DOT) barge canal maintenance operation and eventual relocation. The City would become a catalyst for directing the site redevelopment and initiating various improvements in infrastructure and area amenities. Primary responsibility for the redevelopment of the proposed harbor should be given to the Syracuse Lakefront Development Office. This office would coordinate the actions necessary to achieve a critical mass of short term uses that would in turn stimulate new investment into later phases of the project. Also, a mechanism would be developed that would allow for the sale or long term lease of these lands to a development entity, either public or private. Currently, state constitutional provisions prohibit transfer of ownership of canal lands. Private use of State lands adjacent to the Barge canal is allowed via 30 day revocable permits.

The general intention of the plan is to use the existing barge canal and basin as the centerpoint for a diverse mix of uses and activities. Opportunities to create marina spaces and increase waterfront frontage was explored by creating new canals and marina basins along the edge of the existing canal. The plan attempts to create a


SYRACUSE INNER HARBOR
PROPERTY OWNERSHIP
LEGEND
INTERSTATE 81
INTERSTATE 690
BARGE CANAL
ONONDAGA LAKE
CONRAIL

moderately scaled urban character for the district. Streets and public spaces help to unify various old and new structures. The plan envisions a continuous pedestrian pathway system on both sides of the canal, around the central basin, and connecting to the "Creekwalk" system leading to downtown Syracuse and to the planned trail system around Onondaga Lake.

The study area was divided into a number of subdistricts by land use (Figure 8). The subdistricts included a: "Special Harbor District-Mixed Use" retail, restaurant, office, hotel and residential uses, a "Regionally Important Complex" e.g. office park development, a Regional Park, Housing, a Regional Retail and Office District, Franklin Square Extension, and a Light Industrial/Office district.

The project area was analyzed with respect to six primary factors: existing property ownership, site characteristics, view analysis, circulation, site opportunities and constraints, and present area projects.

Market trends and likely development potentials for four primary uses were examined: marina, retail/restaurants, housing and cultural/recreational facilities. The plan proposed the following mix of uses:

- A marina complex geared to the regional boating population and users of the New York State Canal System, with tour boats, diner cruises and specialty craft.

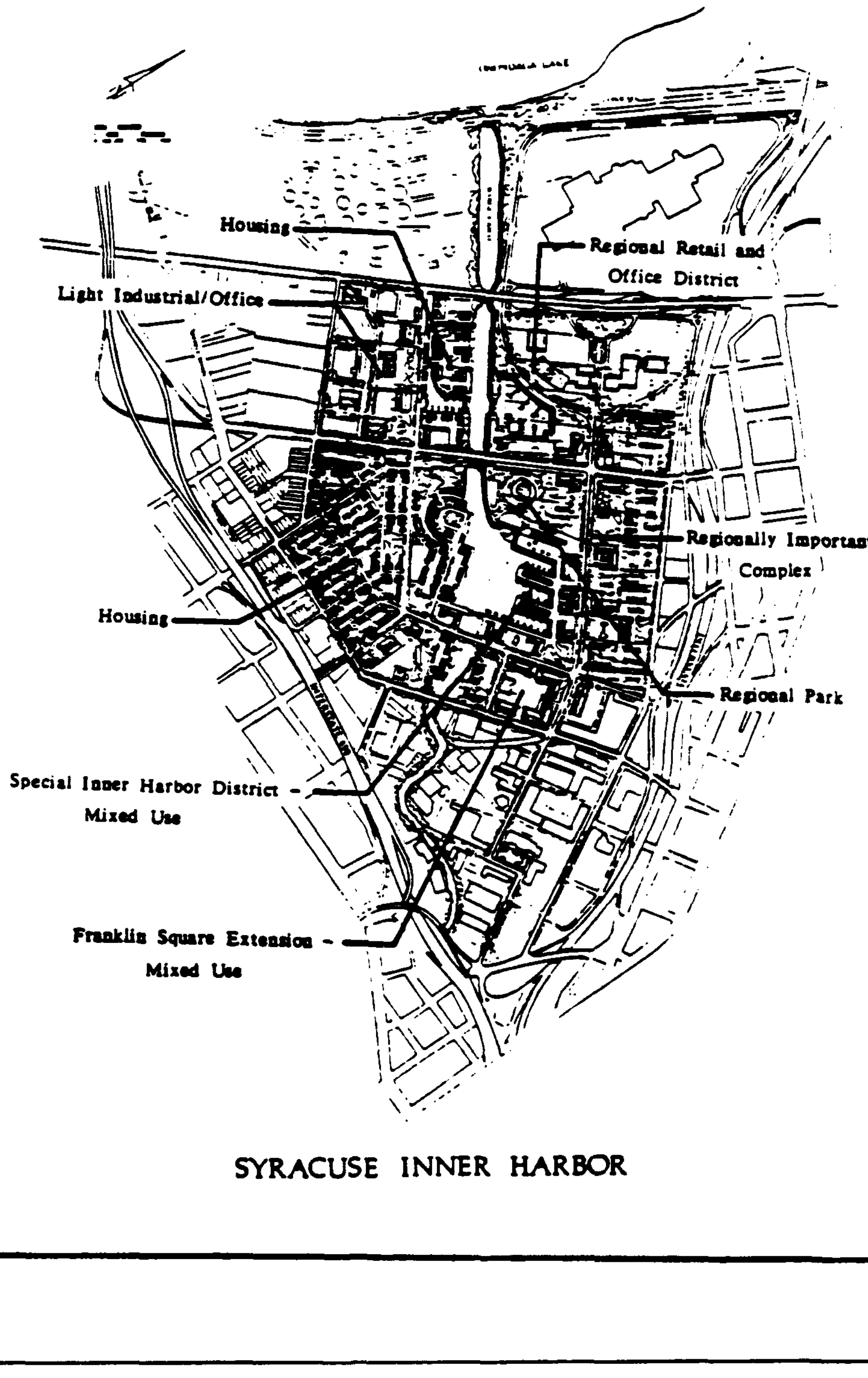
- Restaurants and retail facilities designed to attract patrons from around the region.

- Waterfront housing

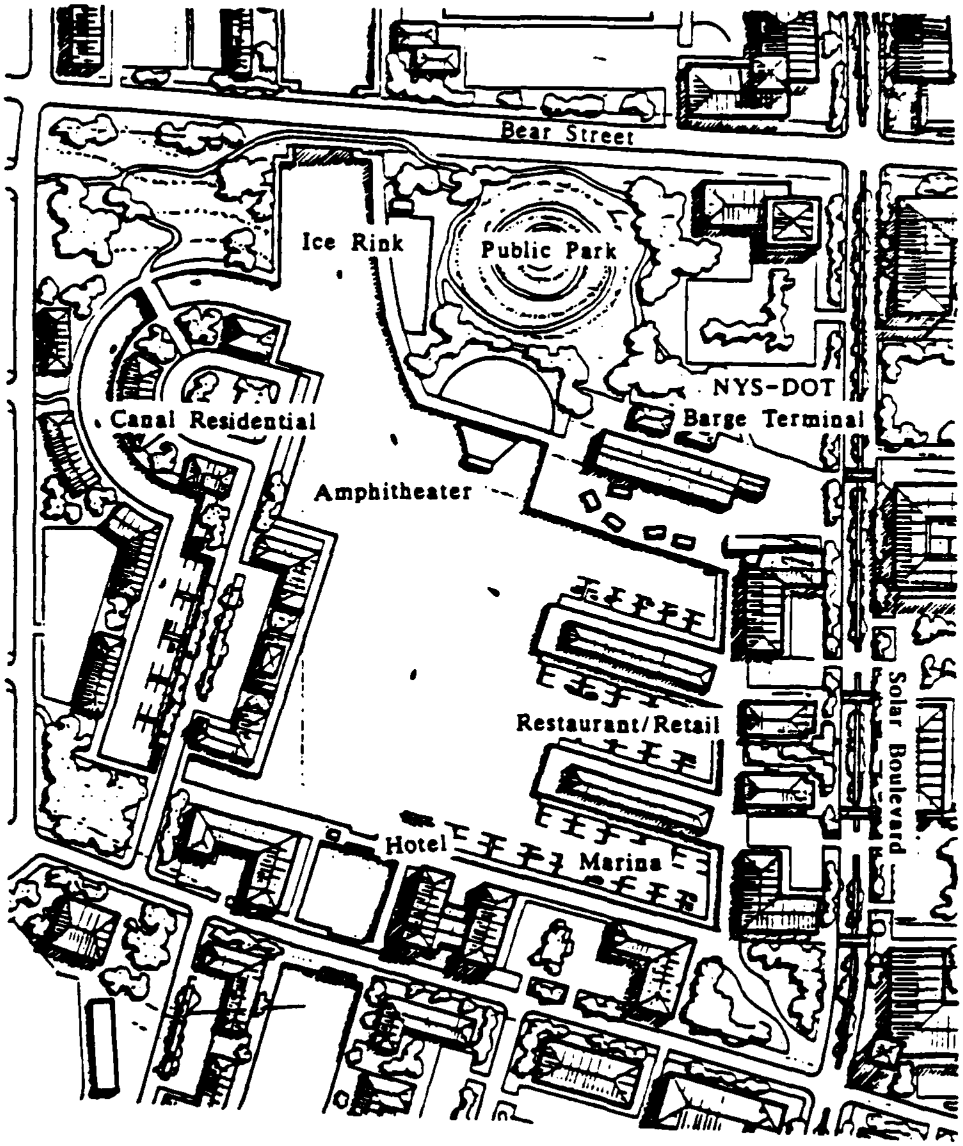
- A major public park.

Development of these mixed uses would take place in a two phase operation. The first phase would be a five year period from 1990 to 1995. This phase would emphasize the development of active, market supportable uses. These uses would draw additional substantial investment to the harbor area and the surrounding Oil City area over the mid to long term.

Phase 1 investments would take place in the Special Inner Harbor District. (Figure 9) Investments would consist of four major elements: a marina, a restaurant and retail pavilion space, new residential units (rental apartments and condominiums) and a harbor park (an amphitheater/performance pavilion/festival space, a family skating



SYRACUSE INNER HARBOR



SYRACUSE INNER HARBOR
Special Inner Harbor District

facility, a waterfront promenade, gardens and wintergarden greenhouse, and a harbor headquarters.

3.2.3.1. Marina. The marina complex would be geared to three distinct markets. The first would be residents of the metropolitan area who wish to store a boat at a centrally located facility with immediate access to Onondaga Lake and the New York State Canal system. The second market includes boats from other areas. The third market consists of people who wish to take advantage of various tour boats, dinner cruises and other specialty craft docked at the harbor.

Phase I of this facility would have 150 slips, 50 of which would be set aside for transient use. These slips would accommodate an average sized vessel of about 28 feet. Winter storage for 100 boats could be provided on site. The marina is envisioned as providing a range of support services and facilities such as a fuel station, facilities for pumping out holding tanks of transient craft, and administrative space.

3.2.3.2. Restaurant And Retail Pavilion. Market studies indicated the study area would support a restaurant program of approximately 20,000 gross square feet. This program would include a 7,500 square foot "tablecloth" restaurant with a strong orientation towards the marina and waterfront. The atmosphere would be moderately upscale and geared to a lunch and dinner crowd. A bar/nightclub/restaurant of approximately 12,500 feet would comprise the other establishment. This facility would be oriented to a younger market, potentially with outdoor dining and activity areas. In addition 10,600 square feet of retail space would be developed to support the marina, housing, and public recreational components. Retail tenants could include a marine supply store, harbor oriented gifts, a food store or deli, and miscellaneous retail (cleaners, florist etc.).

3.2.3.3. Residential. The market analysis indicated housing would be well received if it were combined with additional area wide amenities, and improvements to the harbor. Phase I housing would consist of 250 condominiums units at an average density of 14 to 20 units per acre. There would be 100 rental and 150 "for sale" housing units.

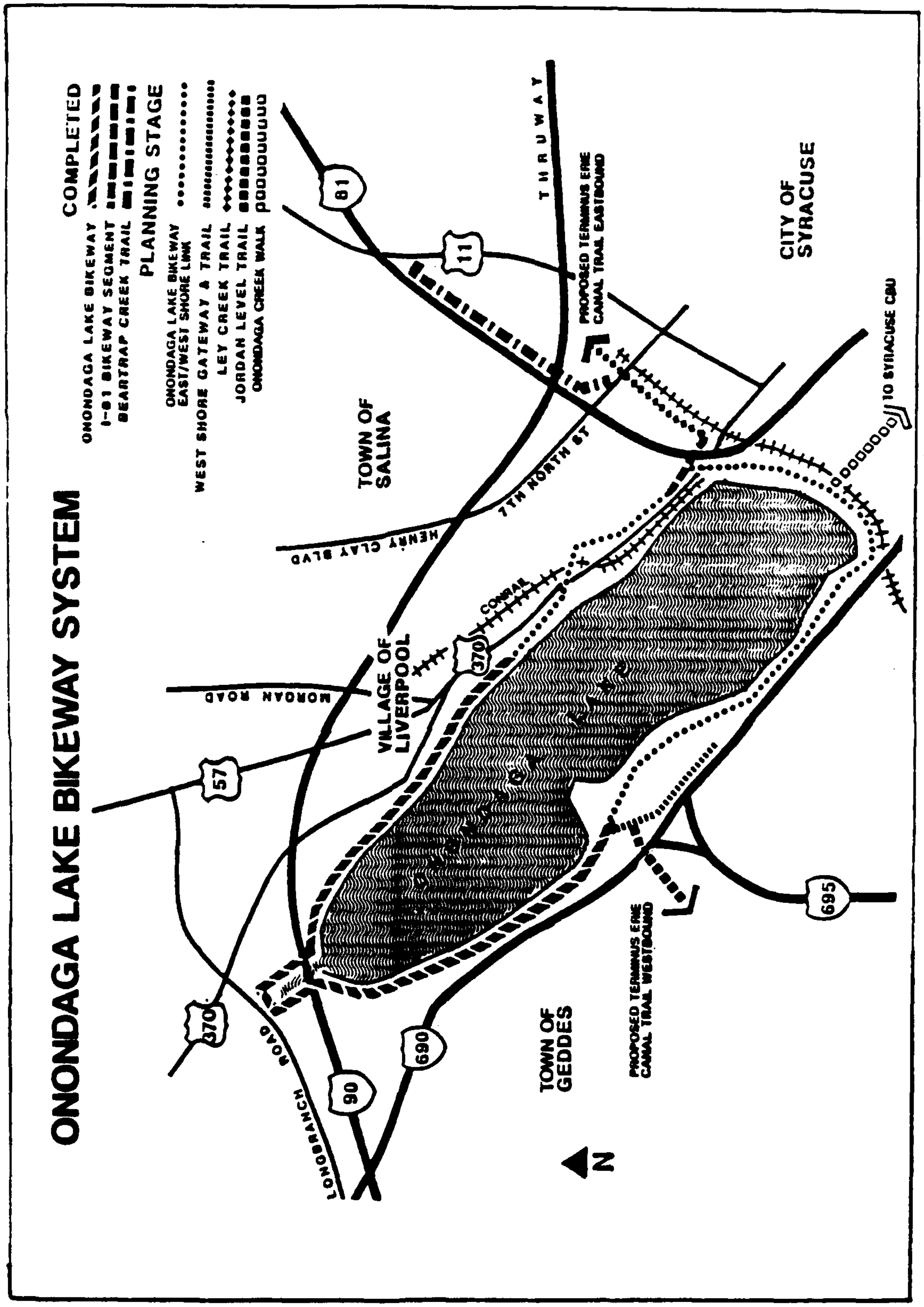
3.2.3.4. Harbor Park. A major public facility is a key to the Harbor area's redevelopment. Visions of the park include the following five components. The first is an amphitheater or performance pavilion coupled with sufficient space for community festivals and events. Theater elements would be capable of supporting symphony, stage and opera performances during good weather. Seating could be provided in an open lawn capable of supporting audiences of 3,000 to 5,000. The second is a family ice skating facility with maintained, refrigerated ice, lighted for nighttime use. The facility would include a staffed pavilion for skate rental and warming, potentially with a snack bar or other nominal food service facility. A waterfront promenade would be a key to providing virtually continuous public access to the shoreline and should include a variety of spaces for seating and overlooks the

canal. Another feature would be a "winter garden" complex of greenhouses or gardens to provide year-round activity and color to the area. Such a facility could be developed in the context of research needs or programs by various educational institutions. Finally a harbor headquarters would be developed to effectively serve as a welcome center and visitor headquarters for the harbor area. This facility would offer the opportunity to link the canal harbor history with its current reuse and redevelopment activity, provide information on its ongoing environmental improvement, and promote various special events and activities anticipated at the harbor.

3.2.3.5. Harbor Costs and Revenues. Total Phase I public sector costs are placed at $15.3 million. This includes $4.4 million for land mitigation or environmental remediation, $7.4 million for infrastructure investment costs, development of the Harbor Park facility at $2.5 million and $1 million to consolidate the DOT Maintenance Facility. Private development costs would total $30.5 million for Phase I. These costs would include a 150 slip marina ($2.3 million), 100 rental housing units ($6.6 million), 150 for sale housing units ($18 million) and 30,000 square feet of retail/restaurants ($3.5 million).

Phase I is expected to produce 654 construction jobs and 78 permanent jobs. These employees, based on an annual payroll of approximately $1.5 million, will in turn pay just over $44,000 annually to the State in income taxes. Estimated annual taxable sales in Phase I is $9.2 million. This results in nearly $650,000 annually in sales tax receipts. Also Phase I development projects represent an estimated assessed value of $7.4 million. Current assessing practices would generate nearly $1.9 million annually in local property tax revenues from the Phase I development projects. (The land is currently under State ownership which generates no property taxes.)

3.2.4. Bikeway The development of eight miles of bikeway around the east, south and west shores of Onondaga Lake have been proposed by the Onondaga County Department Of Parks and Recreation (Figure 10). This proposed bike path, when connected to the existing 5 miles of bikeway around the lake, will provide a recreational pathway around the entire lake. The "Draft Design Report" on the findings of design and environmental studies developed for the project was completed in September, 1990. The report concluded the project would pose no environmentally significant impacts. Also, the project would be compatible with parkland development plans. The completed system, in conjunction with major feeder trails, would reach a number of major state and regional destinations. Some of these destinations are: the Erie Canal Trail, the New York State Fairgrounds, the Central New York regional market, The Carousel Center, downtown Syracuse, Franklin and Armory squares and the proposed 800 acre Oil City redevelopment project of mixed residential, office, and retail land uses.


ONONDAGA LAKE BIKEWAY SYSTEM
COMPLETED
ONONDAGA LAKE BIKEWAY
I-81 BIKEWAY SEGMENT
BEARTRAP CREEK TRAIL
PLANNING STAGE
ONONDAGA LAKE BIKEWAY EAST/WEST SHORE LINK
WEST SHORE GATEWAY & TRAIL
LEY CREEK TRAIL
JORDAN LEVEL TRAIL
ONONDAGA CREEK WALK
THRUWAY
81
11
PROPOSED TERMINUS ERIE CANAL TRAIL EASTBOUND
CITY OF SYRACUSE
TO SYRACUSE CBD
TOWN OF SALINA
7TH NORTH ST
HENRY CLAY BLVD
CONRAIL
370
MORGAN ROAD
VILLAGE OF LIVERPOOL
57
695
PROPOSED TERMINUS ERIE CANAL TRAIL WESTBOUND
TOWN OF GEDDES
690
90
LONGBRANCH ROAD
N

3.2.5. Summary The above studies and projects indicate there is a high degree of coordination and involvement over directing and planning the future land uses around Onondaga Lake in particular, at Syracuse Harbor and for the County in general. Planning involvement and coordination runs from the County level to local business and industrial users. The acknowledgement of alterative goals, multiple needs and limited resources to accomplish them is highlighted by the Onondaga Lake Master Development Plan. This study, using the "Onondaga Counties Development Goals and Policies" as a general framework for development goals, is taking into account current land use patterns and ownership, completed development projects, and over 30 proposed development projects/on going studies affecting Onondaga Lake, in developing a land use master plan for the lake. The result will be a coordinated, integrated land use development plan for Onondaga Lake that is compatible with all potential county development plans and objectives.

4. Beneficiaries

4.1. Introduction

Based on the various proposed alternatives offering varying levels of water quality improvements at estimated costs that vary in magnitude, the questions, *Who would benefit?* and *To what extent would they benefit?* become important. Typically, the primary impetus behind water quality improvement actions is bettering the environment as a whole and therefore it can be deemed as the primary beneficiary from such actions. In turn, economic based interests would benefit from the resulting improved environment. Typically, benefits associated with water quality improvements are measured as the change in value to recreation users and the intrinsic benefits that accrue to both users and nonusers. Intrinsic benefits consist of two types: option value and existence value. Other benefit types linked to water quality improvements include increased land value, reduction in operation and maintenance costs, and increased net income to commercial operators.

4.2. Future Development

Based on heightened public interest, media attention and political pressures from all levels of government there exists a certain expectation that the Lake will indeed undergo cleanup. Though the degree of this expectation may vary among interests, there is the common thread of belief that something will eventually be done. This belief is evident by multi-million dollar investments either now in planning or projects already in the ground. Numerous projects that are planned make evident the critical role that Onondaga Lake plays in future land use plans for both public and private investors. The Onondaga Lake Master Development Plan has been drafted based on the explicitly stated assumption that the water quality of Onondaga Lake will be swimmable and fishable within 10 to 15 years. Though this expectation may have a low probability of occurring given numerous fiscal and institutional constraints, it is regarded with high importance with respect to future development plans.

4.3. Alternative Plans

This investigation has formulated numerous single goal and multiple goal alternatives. Each alternative is comprised of combining a series of independent measures aimed at improving various aspects of the water quality problem. Alternatives were designed to meet pre-established restoration goals. These goals include providing water quality levels to meet standards set forth by New York State for the following uses: swimming (and other water contact sports), cold water fishing and potable uses.

4.4. Perceptions of Users

Future activities in and around Onondaga Lake that may be influenced by any proposed cleanup actions will therefore be benefitted to some degree or another. The resulting benefit of any cleanup alternative is usually based on the reaction of people. The problem of a polluted lake includes perceptions of detraction to potential users of lake dependant or related activities. The converse is therefore also true: elimination or reduction of pollutants in a lake leads to perceptions of the betterment to potential users. The benefits associated with the change in these two conditions can be measured by a change in the value to users (willingness to pay) and change in level of use (quantity participating).

4.5. Recreation

The primary appeal of water bodies located near urban areas in the Northeast has shifted from industrial use potential and transportation advantages to recreational use. Water based recreation not only provides a basis for economic growth in a lucrative tourist sector but also enhances other sectors such as retail and services. Development plans for areas around Onondaga Lake focus on the recreation potential for the Lake in both water dependent and water related activities.

4.5.1. Water Dependent Activities These activities require water in their use. Activities such as boating, fishing and swimming are in this group. Water quality improvements will benefit water dependent activities to different degrees based on the perception of the changes to the users. Water dependent activities requiring little or no physical water contact are not likely to benefit much from changes in water quality unless they are noticeable to users. Obvious changes in water appearance (clarity) or odor would result in a more dramatic change in value to users.

4.5.1.1. Boating. Boating on Onondaga Lake is highly under utilized. This is due in part from its reputation fostered by negative media labelling the Lake as one of the most polluted lakes in North America. Logistically, Onondaga Lake offers advantages not available to most inland lakes by virtue of its connection to the New York State Waterway and ultimately to the Great Lakes or the Inland Waterway. Once water improvements are made and the Lake's reputation improves, its attraction to boaters will undoubtedly experience rapid growth, especially as the Lake undergoes its planned development like Syracuse Harbor, a west end launch site and other public access.

The measurement standard for boating benefits associated with water quality improvements is willingness to pay (WTP) by boaters and their passengers for the improvements. The benefit would therefore be the difference in WTP for the boating experience (user-day) without the improvement and the WTP for the experience with a water quality plan in place. Total change in WTP is comprised of individual WTP increases and the change in the quantity of user-days.

4.5.1.2. Swimming and Other Water Contact Sports. Water contact activities such as swimming, wind surfing, water skiing and diving are more sensitive to changes in water quality then are non-contact activities. The Lake is classified as usable for incidental contact and is therefore used occasionally by wind surfers and water skiers throughout the season. Although there is no ban on swimming in Onondaga Lake potential users refrain from using the Lake as a result of the Lake's poor reputation from continual press coverage. Therefore the value of swimming under existing conditions is nonexistent. The Lake's proximity to a large urban and suburban populace and the beautiful natural amenities give it great potential for swimming as a popular activity in the advent of water quality improvements. If a water quality alternative was implemented removing bacteria, phosphorous and toxins bringing the quality to a swimmable standard, a benefit to all induced users would be realized. All of other water dependent activities would benefit greatly as well. Again WTP is the standard to measure these benefits. If perceptions of the potential users following a cleanup plan is that the water is still not safe, even though the water was in fact safe, the misconception would therefore lessen the benefit attributed to the plan. It is therefore necessary to include a means of promoting the cleanup plan as a component measure of the proposed plan so that the benefits can fully be realized.

4.5.1.3. Fishing. Presently, the Lake provides a warm water fishery; fishing limited to "catch and release" due to high mercury concentration in the fish and sediment. Demand for cold water fishing has experienced tremendous growth in New York State. Onondaga County residents envision the reintroduction of atlantic salmon in Onondaga Lake by the year 2000 (Salmon 2000) assuming the lake will be cleaned up by then. Annual derbies focused on salmon fishing attract anglers by the hundreds of thousands from all over the world. NED Benefits, based on WTP for participation in the enhanced fishing opportunities on Onondaga Lake as well as the change in the quantity of user-days could be substantial. Regional benefits resulting from water quality improvements that provided enhanced fishing opportunities also would great.

4.5.2. Water Related Activities Many recreational activities are enhanced by their proximity to water though the activity is not dependent on the water itself. Hiking, picnicking, camping, bird watching, waterfowl hunting and the like are all activities enhanced by proximity to water. It therefore follows that the value of the experience is affected by changes in water quality. This becomes particularly important when the polluted characteristics include degraded sight and odors as is the case with Onondaga Lake. Like the water dependent activities, enhanced recreation opportunities and an increase in the number of user-days for water related activities would result from the implementation of water quality improvement plans. These benefits are measured as the difference in WTP of users participating.

4.6. Land Value

The value of land is also dependent on the water quality of water bodies in proximity to the land. This is not only true for shoreline property but also for land which may support activities which are enhanced by the water quality improvements. If a water quality improvement plan is implemented on Onondaga Lake, neighboring lands would increase in value. The benefit would either be an intensification benefit, where the land use does not change but becomes more intensively used or a location benefit, where the land use changes to a new higher valued activity. The benefit would be the difference in value of land between the "without project" condition and the "with project" condition. Care must be taken not to "double count" benefits by measuring the increased value in land and also the increase in net income to the activity using that land.

4.6.1. Commercial Many commercial activities are aesthetically enhanced by their presence near clean water bodies. Current plans for lakeside dining are being considered by potential developers of the shoreline. Again the success of restaurants on the shore depends on the volume of customers. Aesthetic differences on the Lake for 'with' versus 'without' a water quality improvement plan would influence the number of customers frequenting the restaurant and therefore also benefits.

4.6.2. Public The shoreline is primarily public ownership. Most benefits to this sector are measured through increased value and increased use as is the case with recreational outputs. Another potential public beneficiary of water quality improvements on Onondaga Lake is water supply utility in the event of a plan providing potable water from the Lake. Typically this benefit is measured as the cost of the least costly alternative supply. Presently the area is serviced by the Onondaga County Water Authority receiving the majority of water supply from Lake Ontario.

4.6.3. Residential Studies have linked sometimes sizable differences in property value between identical structures on identical lot sizes, the only difference being the structures location relative to park land, natural water body, golf course, etc. The differences in the values of property located near a polluted water body as compared with clean water body could be sizable as well.

4.7. Commercial Tour Boat and Charter Benefits

There is the possibility of the addition of a permanent tour boat and dock on Onondaga lake in the event of Lake cleanup. Commercial charters on Onondaga Lake would be inevitable if Salmon 2000 is successful. Net income to the owner/operator (producers surplus) and recreation benefits to users (consumer surplus) would therefore become benefits associated with the implemented plan.

4.8. Cost Reduction Benefits

A water quality improvement plan may also have a positive effect on existing cost for services on or near the Lake. Presently water treatment costs are substantial. Existing dredging costs for the existing Barge Facility as well as the future Syracuse Harbor may be effected with the implementation of water quality measures on Onondaga Lake and its tributaries. Also the cost of disposal for toxic dredge material is great. If the future dredge material under the "with project" condition was no improved so to lessen the cost of disposal methods, then this difference in cost or cost savings could be credited as a benefit to the improvement plan.

5. Evaluation Methodologies

Improved techniques for estimating the 'benefits' associated with water quality improvements have evolved over the last several decades. Willingness to pay remains as the only acceptable standard to adequately measure welfare gains to the nation or national economic development from these improvements. In the previous section, numerous possible benefit categories were identified as being likely with the implementation of a water quality improvement plan. The evaluation of certain benefit categories, like net income to tour boats, dredging cost savings, decreased operation and maintenance costs, increased land values, etc. are relatively straight forward are not the subject of this section. Historically, for most water quality improvement studies the primary emphasis is directed at the value of changed use or consumption particularly in areas including recreation or water supply. However other studies aim at capturing psychic value gains for intangible outputs. The value measured in some instances can be linked to the perceived change in environmental welfare. Examples of this are valuing a belief that a proposed project would lessen or eliminate the likelihood of extinction of a species or cause a decrease in the rate of birth defects. Therefore using some methods of evaluation the perception of the affected population is a very important factor influencing the change in value associated with water quality improvements.

Three general methods comprise the most popular techniques employed to measure the change in value associated with proposed water quality improvements. These are contingent valuation, travel cost, and hedonic models. The following sections describe these methods and provide a critique of their use for evaluating impacts like those proposed for Onondaga Lake. [1]

5.1. Value of Recreation

Economists are in general agreement that the value of a recreation day of boating, water skiing, waterfowl hunting, etc. is measured by its true worth to the recreationist. It follows logically that there is a point of inconvenience to recreationists due to the degradation of water quality beyond which satisfaction with the experience diminishes to the point that the recreationist would be willing to pay less for the experience than if water quality were within an acceptable range for the activity being pursued, in terms of aesthetic factors that enhance the experience. We would expect that as water quality deviates away from this acceptable standard that recreationists on average would pay less and less for the experience. Moreover, some

[1] These sections were largely extracted from the unpublished Work Group Report on Non-Riparian Recreation prepared for The International Joint Commission Water Levels Reference Study, Phase I, June 1989.

recreationists would stop participating and others would participate less often. Thus, not only would recreationists pay less per trip, they would also take fewer aggregate trips. As a result, as water quality declines the total value of the resource for a given type of recreation would decline to a point where presumably it would be totally unusable and thus would have a value of zero for a specific form of recreation. This is the case for swimming as an activity on Onondaga Lake today.

There is no genuine market on Onondaga Lake for swimming days, boating days or other types of recreation days that would make their value obvious. Boaters pay transportation costs, food and lodging expenses, launching fees, and other costs that might provide some insight as to minimum levels they are willing to pay. But no one actually charges them a fee for a recreation day (except for charter boats). Because boaters and other recreationists are also unfamiliar with buying recreation days, it is doubtful that they would know exactly how they would value a given type of recreation experience. However, limited experiments have shown that they can reasonably approximate this value.

Because of the difficulty in assessing willingness to pay (WTP), the Federal government has traditionally used fixed unit day values as an estimate of actual WTP. While these values may have some credence, it is recognized that they were not derived empirically, and likely are not very accurate. As a result, Federal agencies are now encouraged to use empirical techniques to estimate recreation day or trip values.

Over the past 15 years especially, a great deal of progress has been made in advancing methods to estimate WTP to participate in outdoor recreation activities. Three methods in particular have shown strong promise in this regard and are widely accepted by leading resource economists: contingent valuation (CV), the travel cost method (TCM), and the hedonic pricing method (HM). Each of these techniques has several variations in how it has been applied, and each has strengths and weaknesses relative to particular types of valuation situations. These methods will be reviewed and critiqued below:

5.2. Contingent Valuation Method (CVM)

CVM is a direct survey technique that involves asking individuals for their personal valuations of increments or decrements of unpriced goods by using "contingent markets."

5.2.1. CVM Overview Contingent markets define the good, service, or amenity of interest, a status quo level of provision, the increment or decrement involved, and other relevant factors such as the any change in the institutional structure under which the good is to be provided, and the method of payment (adapted from Randall et al. 1983). It is now probably the most frequently used technique in environmental benefit assessment because it is the most easily adaptable of the three

techniques to any situation. One simply summarizes the situation, states it as concisely as possible, and asks a survey audience how much more or less they would be willing to pay (or be paid) under any proposed changed condition.

5.2.2. CVM Concerns Although the concept of CVM in economics has been around for decades, two early criticisms hampered its use in environmental and natural resource settings until 1978. The first can be succinctly stated, "Ask a hypothetical question and you will get a hypothetical answer." There are a number of possible dimensions to hypothetical bias. People may genuinely not know what they would do in the hypothetical case because they have never been in that particular situation, they do not understand all of its ramifications, and the more hypothetical the situation, the less incentive there is for the respondent to seriously consider the scenario and try to arrive at an accurate answer. Interest in CVM continued nevertheless over the past decade because requirements to quantify environmental costs and benefits increased and for many broad applications there was no other usable method. Very limited experimental research has found that in specific situations individuals can estimate their behavior (willingness to pay) in hypothetical situations.

The second early concern about CVM was expressed in 1954 by the noted economist Samuelson, who argued that CVM would fail because it is in everyone's personal interest to send false signals - to underestimate what he/she would really pay for something (in case it were decided to actually charge them that amount) or to overestimate what they would have to be paid for something that would be taken from them. Freeman (1979) pointed out that the more hypothetical the question, the less incentive for "strategic bias" on the part of the respondent. However, the more hypothetical, the less the motivation for the respondent to give a carefully considered answer.

The state of CVM now is that it is certainly accepted, but a better understanding is needed of the cognitive process when respondent's answer CV questions. As a result psychologists and other social scientists have begun to team with economists to develop a better understanding of the human thought process in answering typical CV questions to determine biases that occur in answering the questions in order to rephrase questions in a manner that minimizes any such biases. Some research is now available on CVM biases.

Regarding strategic bias, Brookshire et al. (1976) argued that one would expect true willingness to pay bids to approximately follow a normal distribution. For example, in a situation in which a resource is being considered to be taken for development, strategic bias would cause pro-developers to devalue the resource from what they really think it is worth, and environmentalists on the other hand to overstate what they would have to be paid to give up the resource. When all responses are plotted, the curve would tend to be rather flat. In the Brookshire et al. (1976) study involving recreation visitors to Lake Powell, the curve plot was very near normal,

leading them to believe that strategic bias was minimal. They further suggested that if one considers carefully and possibly throws out zero and extremely large bids, strategic bias, if it exists, will have a negligible effect on the bid distribution. In another example, Rowe et al. (1980) obtained the willingness to pay bids, then asked respondents at a later point in the survey to place themselves on a conservationist to developer continuum. The correlation between development/conservationist attitude and willingness to pay (WTP) was insignificant, leading the authors to conclude that strategic bias was minimal in this study.

A basic precept of economic theory that applies to CVM is that people have perfect knowledge of savings and spending options and trade-offs over the whole range of goods and services available. Several scientists have done controlled subjects such as reminding versus not reminding respondents of budget constraints and expenditure trade-offs. The consistent conclusion has been that people formulate their bids in a market-like context in which they are aware of other income tradeoffs.

Another potential bias of concern to those using CVM is whether the starting point in a bid, which is chosen somewhat arbitrarily, affects the distribution of values given. Randall et al. (1974) suggested asking different subsamples if they would be willing to pay different amounts and constructing a demand curve based on the results. The two potential sources of bias are (1) that people may interpret the value asked as an appropriate amount to pay as opposed to just a "for example" figure chosen in a value neutral context. and (2) for people who value time highly, boredom may quickly set in any lengthy iterative bidding context, with the result that respondents do not carefully consider their WTP succeedingly higher values. Studies are not consistent on this topic. Some (e.g., Rowe et al. 1980, and Boyle et al. (1985) have found significant differences in results based on differences in the starting point for the bidding, while others (e.g., Brookshire et al. (1980), Brookshire et al. (1981), and Thayer (1981) found either no differences or insignificant differences.

Two studies (Sorg and Brookshire (1982) and Schulze et al. (1983) investigated the relationship between bids obtained from listing a range of bids on a card and asking respondents to choose the highest value, versus iterative bids. The iterative bids obtained were up to 40% higher, which suggests that iterative bidding may be a vital technique to use in obtaining maximum WTP.

Vehicle bias has also been investigated, with inconclusive results. Respondents are usually given a payment mechanism as part of the scenario in which WTP to pay data are sought. Depending on the nature of the study, entry fees, sales taxes, income taxes, utility bills, and hunting or fishing licenses have been used as payment mechanisms. Depending on one's attitudes about utility rates or other fees listed above, that attitude may influence the WTP answer one gives. Put another way, if the amenity item is cleaner water but respondents already feel that water bills are too high, they may indicate that they would be willing to pay more in some form of taxes than in water bills for the same incremental improvement in water quality.

5.2.3. Willingness to Pay versus Willingness to Accept (WTA) Economists generally agree that when a new or expanded resource is created, or a resource is improved, WTP is the theoretically correct valuation measure. On the other hand, when a resource which the public has a right to is taken away, the correct valuation measure is the least amount that the public would accept to give up that resource.

It has been argued strongly by a number of leading resource economists that theoretically, in a given situation, WTP should approximate WTA. WTP is expected to be slightly less than WTA because WTP is income-constrained, while WTA is not. However, the difference between the two measures would not be large, theoretically.

In reality, just the opposite has been the case. WTA values have typically been several times as large as WTP values. Even in limited experimental cases where real money rather than hypothetical money has been used, differences have remained very large. As a result, valuation experts sometimes look askance today at WTA studies because their value estimates are in many people's opinion too high to be reasonable.

Several rationales have been put forth as to why differences between the two measures are so large. Most professional opinions agree that it is a strong disadvantage for respondents to be involved in bidding on or pricing resource commodities or experiences they have no experience with. Bishop and Heberlein (1986) suggest that in the absence of this experience, people will bid very conservatively. This means that in a WTP study people would bid comparatively low or safe values that they are sure they would pay without more careful consideration of the matter. Similarly, in WTA studies people would bid comparatively high values that they are sure they would accept without more careful consideration of whether they would accept less. This view may not readily suggest which of the two measures is most heavily biased. However, for reasonable compensation amounts for most resources that people are asked to value, the range between 0 and the likely value people will pay is substantially less than the difference between a "reasonable" WTA value and an infinitely large one. As a result, WTP is sometimes used when WTA can be justified as the theoretically correct measure, simply because WTP results are seen as more accurate and even closer approximations to "true" WTA values than WTA study results.

While the above rationales for various biases that cause differences in WTP versus WTA appear to have merit, some experimental work by Knetsch and Sinden (1984) throw serious question on the supposition that WTP should be nearly equal to WTA, except for a "small" income effect. These researchers conducted several real lotteries involving student audiences. While several variations were tried, the gist of the experiment was that a student audience was given a ticket for a drawing of $50 cash or $70 in merchandise from the college bookstore. Half the class was asked to pay $2 to keep the tickets. The other half was offered $2 cash in exchange for the ticket. Low dollar amounts were chosen to minimize the income effect. Students in the two groups negotiated their decisions individually to minimize peer pressure in either direction. In several such similar experiments, statistically significantly higher

numbers refused to accept the cash payment, compared to those who were willing to pay cash for the lottery ticket. From one experiment in which equal numbers of Group A were asked to pay amounts ranging from $1 to $4, and equal numbers of Group B were offered the same amount as payment, the average WTP was estimated to be $1.28; the average WTA was estimated to be $5.18. These experiments cast doubt on the claim that the differences between WTP versus WTA values are due primarily to either income effects (necessarily), to hypothetical biases (as these experiments used real money), or to inexperience at bidding games. Knetsch and Sinden (1984) note that in one experiment in which peers were asked to advise others as to what they should do, no significant differences were found in the advice given on WTP versus WTA.

One unsubstantiated reason for large WTP versus WTA differences may be that people view money in hand differently from other money, even when the latter is certain-to-be-received money. The concept has not been thoroughly researched, but we know that people treat money in hand as a scarce commodity. Furthermore, depending on their upbringing, people develop values about money that have ethical, moral, and religious components or associations. For example, "Hard-earned money is not to be squandered." "A penny saved is a penny earned." There is a stewardship-like responsibility associated with money, somewhat similar to that associated with natural resources: while a small budget for personal entertainment or pleasure is permissible, the majority of income not essential for cost of living should be used in ways that enhance the individual, the family, and the community. Thus, rather conservative, carefully considered WTP values are formulated.

When offers to be paid (WTA) are being considered by individuals, there are two distinctions in addition to the income effect that result in a different value formulation. First, related to the above paragraph, until a negotiation is completed, this is not money that people worked for or have special responsibilities to accept and to use wisely. It is someone else's money. So the "ethic" toward money is different in a WTP versus a WTA transaction. Second, it can perhaps be argued that in a WTA situation, one has access not only to a good, a service, or an experience, one also has a right or an option to use it. The "owner", whether of a fishing trip to Lake Onondaga or a lottery ticket, is being asked to sell not only a good, service, or experience, but also an option or a right. In many cases, including the lottery ticket experiment, the person can not take the true monetary value to him/her of what is being sold (if this value were known), once the sale has been completed, and turn around and rebuy what was given up. If this were the case, WTA values might be closer to WTP values.

5.2.4. Summary It should be clear from the previous discussion that CV studies are far from bias-free. In fact, one might argue that they are still as much an art as a science. For example, in some recreation studies upwards of ten percent of respondents indicate that they will pay no more than what they actually paid for the

experience. Theory would indicate that this is occasionally a correct value, in a situation where an individual took only one trip and received no consumer's surplus, but it is an unlikely value for anyone who takes two or more trips, as they would be returning knowing they will likely receive no net gain for the experience. In many studies all 0 responses are eliminated from the data to be analyzed.

On the opposite extreme, in some studies perhaps 15 percent of respondents indicate that they would be willing to pay very large additional values. These can run in the hundreds or thousands of dollars. We know such situations exist, such as a once in a lifetime distant big game hunting trip or a trip to "collect" a rare bird and add to one's lifetime viewing list. There are relatively few such occasions in which consumer's surplus values are extremely large. Typically, when these values reach a significant proportion of one's annual income, their accuracy can be doubted. As a result, CV studies usually eliminate these very large values. But where does one draw the line? Wherever the choice, it is arbitrary.

Despite the biases inherent in CV, this method now appears to be more widely used and gain more research attention than either the travel cost or hedonic methods. This is undoubtedly due to the almost limitless variety of applications for which the method can be applied.

5.3. The Travel Cost Method (TCM)

The essence of the TCM is that the cost of travel to a recreation site can be used as a proxy for the price that people pay for the site's nonmarket services. Therefore we can estimate a demand curve for the site that will show how many people will visit the site at alternative costs of travelling to it.

5.3.1. TCM Overview The concept of TCM dates from Hotelling's suggestion in 1949 that it would be a possible way to value our national parks. The method was more fully developed by Clawson (1959) and illustrated with data from several national parks.

The TCM initially used a zonal model. Visitors to a site are given a survey from which the distance they drove to the site is determined along with demographic factors such as age and income that affect demand. People are then grouped into distance zones (concentric circles around the site). Knowledge of how far the average person in each zone travels to the site and cost per mile are used with knowledge of the average number of visits made to each site by residents of that zone to plot a demand curve. Price is measured by travel cost; quantity demanded is measured by the average number of visits to the site. When expenditures are subtracted from the appropriate area under the demand curve, consumer surplus is found.

An individual observations model is also used in TCM, based on the same concepts. However, it does not group visitors to the site by zones of origin, so it does not need to deal with average individual characteristics. Instead, regression

analysis is typically used to measure the value of the site as a function of travel costs and other variables that influence recreational demand - income, age, the cost of travel to substitute recreation sites, etc. This yields an estimate of the consumer surplus individuals receive from taking a trip to the site.

More recently it has been realized that individuals who visit recreation sites "pay" more than travel costs in addition to their other expenses. They also spend time. Research continues to determine an accurate way of placing a value on the time spent by individuals. In some cases people take time off from work for trips in which the opportunity cost is in fact their actual wage rate. Probably most trips are taken during leisure time, which still has some value, assuming that in absence of a trip to a recreation site people would have pursued an alternative leisure activity or done something of personal value. In the absence of specific information from each individual, economists have most often used a figure of 1/3 to 1/2 the individual's wage rate to estimate the value of time.

5.3.2. TCM Concerns One of the most difficult aspects of TCM to deal with is that of multipurpose trips. A profile of visitors to Niagara Falls, as an illustration, would show visitors from all over the world. Even though Niagara Falls is a nationally known tourist attraction, as the distance from the Falls to the residence of visitors increases, we would find that the proportion of people who left their home to go specifically to Niagara Falls and to no other attractions decreases sharply. For a family from the South or Midwest who takes a vacation to the Northeast or to Canada, and who spends an hour or two at Niagara Falls, the TCM allocates their entire travel cost, and hence the entire consumer surplus of the vacation to Niagara Falls. Although some attempts have been made to apportion part of the trip to a given site, a satisfactory method has not been developed. The TCM has often been used as an afterthought, using survey data collected for another purpose to try to value a particular site. If the effect of multi-purpose trips is to be adequately accounted for, detailed trip information as well as site visitation information will be needed.

Related to the above, the TCM assumes that the utility of travel is exactly offset by the cost involved. As a result, all consumer surplus is attributed to benefits at the recreation site. If particular individuals take more trips to the site either due to multipurpose trips or because they derive enjoyment from the trip itself, value estimates from the TCM may be biased.

The value of time, discussed above, is another biasing factor. Again, detailed information on whether a trip is taken on leisure time or time taken off work, and the probable use of that time had the trip not been taken is needed to accurately estimate the value of time. It is also not clear how to value the time of homemakers, children, retired, and unemployed people who are not in the labor force. Typically arbitrary assumptions are used.

Another biasing factor is that the TCM treats a site as though it is a consistent

good for everyone who visits it. This may not be a strongly biasing factor for a small site with access to a single activity, such as a beach used exclusively for swimming/sunbathing. But consider a park on a lake where people use a trailered boat or their boat berthed at the park marina and go salmon fishing. Someone else may go waterskiing. But someone else may go for a special park event, and yet another party may stop for a picnic or a day use activity such as hiking. The TCM has no way to distinguish these differences unless the sample is limited to one group. Given similar travel distance, incomes, availability of substitutes, etc., the consumer surplus of the picnicker will be estimated to be about the same as that of the salmon fishermen. For Onondaga Lake, another problem is encountered by not having adequate user origin destination data for activities that will be offered following any lake cleanup actions. It therefore would be necessary to identify an analog lake with similar demographic and socio-economic surroundings that offers activities that would occur under the proposed plans at Onondaga Lake and that has historical origin-destination data for these activities. Finding the appropriate data would likely be difficult.

Despite all of these shortcomings, comparative studies using several two or three valuation methods indicate that the TCM can provide reasonable estimates of consumer surplus. There have been many cases in which a resource has been threatened or there has been a political reason to estimate its value. With neither the time or money to design a proper valuation study for that particular purpose, an existing study of visitors to that resource is "retrofitted" via TCM to estimate the value of the resource. It is highly unlikely that such an effort will yield reasonably accurate results. Just as a CV study has to be very carefully designed, so does a TCM study.

Even if the several TCM biases can be held in check, the TCM has much more limited use than the CVM. The CVM can be used to estimate how much people value resources that they do not travel to. Thus, Kay et al. (1987) were able to estimate the New England public's value of Atlantic Salmon restoration, even though a very limited number of anglers now fish for these fish in Maine. People who never expect to fish for them still value them. The best that could have been done with TCM in that same study was to value the current limited Atlantic Salmon fishery in Maine. The CV analysis can provide the mechanism for the broader analysis of potential program benefits desired.

The TCM could not be used to relate trip values to differences in air quality or water quality unless such differences could be related directly to less travel to a given recreation site. In the case of water quality improvements on Onondaga Lake the TCM could perhaps be used if one assumed that as water quality improved trips would increase proportionately.

changes in water quality. It is the most flexible of the three valuation techniques. It also represents a more direct approach of estimating benefits. While people do not always know what they would do in hypothetical situations, the research to date indicates that respondents use little strategic bias. The vast majority try to provide an accurate estimate of what they would pay in a given situation.

The greatest impact from proposed alternative water quality improvement plans would come from existence or option benefits from general households in the population-at-large. The greatest user impact will be from recreation users on the Lake, probably fishing creating the greatest benefit. The problem with CVM for measuring benefits for proposed changes in water quality is in the perceptions of survey respondents. Their ability to respond to "How much they are willing to pay" is predicated on how well we can describe the conditions of improvement in a practical way that has meaning to the potential buyer. CVM works best where the proposed plan of improvement is well defined and can be described so that what potential users picture of the proposed plan portrays what will actually occur and that the preconceived notions are all similar among the respondents.

The details of the methodology used for a study of water quality improvements on Onondaga Lake will necessarily depend on available resources. The optimum number of recreation groups examined by primary surveys, the optimum type of survey instruments to use (mail versus personal contact (i.e., telephone surveys), and the recommended strata and sample sizes used all depend on available resources. In terms of obtaining accurate estimates of the impacts of changes in water quality by plan on Onondaga Lake, a skeletal outline of the preferred methodology for identifying impacts on boating-related activities would be as follows:

1. Obtain a random sample of registered boaters deemed representative of without project and with project users.

2. Implement a survey to determine:

    a. Boating/fishing use patterns in the previous year;

    b. Expenditures for a typical trip;

    c. Estimate of average consumer surplus for trips in which enjoyment was not impeded by poor WQ;

    d. Estimate of number of trips taken in which poor WQ reduced the enjoyment of the trip;

    e. Estimate of average consumer surplus per trip for (d);

changes in water quality. It is the most flexible of the three valuation techniques. It also represents a more direct approach of estimating benefits. While people do not always know what they would do in hypothetical situations, the research to date indicates that respondents use little strategic bias. The vast majority try to provide an accurate estimate of what they would pay in a given situation.

The greatest impact from proposed alternative water quality improvement plans would come from existence or option benefits from general households in the population-at-large. The greatest user impact will be from recreation users on the Lake, probably fishing creating the greatest benefit. The problem with CVM for measuring benefits for proposed changes in water quality is in the perceptions of survey respondents. Their ability to respond to "How much they are willing to pay" is predicated on how well we can describe the conditions of improvement in a practical way that has meaning to the potential buyer. CVM works best where the proposed plan of improvement is well defined and can be described so that what potential users picture of the proposed plan portrays what will actually occur and that the preconceived notions are all similar among the respondents.

The details of the methodology used for a feasibility level study for water quality improvements on Onondaga Lake will necessarily depend on available resources. The optimum number of recreation groups examined by primary surveys, the optimum type of survey instruments to use (mail versus personal contact (i.e., telephone surveys), and the recommended strata and sample sizes used all depend on available resources. In terms of obtaining accurate estimates of the impacts of changes in water quality by plan on Onondaga Lake, a skeletal outline of the preferred methodology for identifying impacts on boating-related activities would be as follows:

1. Obtain a random sample of registered boaters deemed representative of without project and with project users.

2. Implement a survey to determine:

   a. Boating/fishing use patterns in the previous year;

   b. Expenditures for a typical trip;

   c. Estimate of average consumer surplus for trips in which enjoyment was not impeded by poor WQ;

   d. Estimate of number of trips taken in which poor WQ reduced the enjoyment of the trip;

   e. Estimate of average consumer surplus per trip for (d);

f. Estimate of number of additional trips not taken because poor WQ prevented such trips;

g. Information on dates when boating enjoyment was reduced or prohibited (memory recall will be a problem);

h. Information on specific area of problems, type of problems and nature of needed solution (or individual measure that would most likely remedy the problem).

3. Analyze sample data and extrapolate to the boating population to estimate benefits lost or not realized that are attributable to poor WQ.

Additional considerations for such a survey are parallel to those of survey research generally. We must determine whether we want to characterize impacts of poor WQ, extrapolating only to Onondaga Lake. The level of extrapolation is critical to determining the required sample size. Then, if a mail survey is implemented, it is important to overcome the biases otherwise caused by nonrespondents. Frequently nonrespondents differ from respondents with regard to the characteristics of interest to the study. For example, if the study were to be characterized as one to determine the value of benefits lost to boaters who were negatively impacted by poor WQ, we would expect fewer boaters who were not affected to respond. If we expanded our sample estimates directly to all boaters, we would likely overestimate substantially the benefits lost. Follow-up reminder letters and a brief telephone follow-up to nonrespondents are typically implemented to lower nonresponse bias as much as possible, and then to estimate the remaining bias.

An analogous procedure to that used for boating could be used for other activities. For some activities, however, the procedure could likely be simplified. For example, concerning water related activities such as hiking or biking, the recreation experience has similar composition at good or poor water quality. As a result, the gradations of enjoyment of the experience in conjunction with water quality graduations have less relevance. The important factor is that unless the quality of water improves, certain development plans may never materialize or the sustained negative portrayal of the Lake will keep future recreationist from trying the experience.

The research will have to be better defined before it is clear whether WTP or WTA is the correct parameter to seek data on. WTP would be the correct measure of the value of actions instituted to lessen these disbenefits if impacts were based on correcting naturally occurring conditions that have always been experienced. On the other hand, if waters were being used to benefit say an industrial user, at the expense

of say recreationists, WTA would be the correct technique to use.

Within the CV framework, in addition to expanding the results obtained from seeking the highest WTP bid, the dichotomous choice method should be used. The limited evidence available suggests that this technique more closely represents actual WTP than simply seeking the highest bid, which may undervalue true WTP by 40 to 50 percent.

Literature Cited

Bishop, R. and T. Heberlein. 1986.
"Does Contingent Valuation Work?" Pp.123-147 In R. Cummings, D. Brookshire, and W. Schulze (eds). Valuing Environmental Goods: An Assessment of the Contingent Valuation Method. Totawa, NJ: Rowman and Allanheld.

Boyle, K. J., R. C. Bishop and M. P. Welsh. 1985.
"Starting Point Bias in Contingent Valuation Bidding Games". Land Economics, 61(2):188-194.

Brookshire, D. S., B. C. Ives, and W. D. Schulze. 1976.
"The Valuation of Aesthetic Preferences". Journal of Environ. Econ. and Management 3:325-346.

Brookshire, D. S., A. Randall, and J. R. Stoll. 1980.
"Valuing Increments and Decrements in Natural Resource Service Flows". American Journal of Agricultural Economics. 62(3):478-488.

Brookshire, D. S., R. C. d'Arge, W. D. Schulze, and M. A. Thayer. 1981.
"Experiments in Valuing Public Goods". Pp. 132-172 In V. K. Smith, ed. Advances in Applied Microeconomics. Vol. 1. Connecticut JAI Press, Inc.

Brown, J., T. Brown, G. Jones, A. Sudar, 1989.
Non-Riparian Recreation Work Group Report. IJC Water Level Reference Study, Phase I.

Brown, T. L. and N. A. Connelly. 1985.
"State Parks and Residential Property Values in New York". Pg. 245-254 In Proceedings, 1985 Outdoor Recreation Trends Symposium II. Clemson, SC: Clemson Univ., Dept. of Parks, Recreation and Tourism Management.

Clawson, M. 1959.
Methods of Measuring the Demand for Outdoor Recreation. Washington, DC Resources for the Future, Reprint No. 10.

Dwyer, J. F., J. R. Kelly, and M. D. Bowes. 1977.
Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development. Urbana, IL: Univ. of Ill. Water Resources Ctr. Research Report No. 128.

Freeman, A. M. 1979.
"Approaches to Measuring Public Goods Demands". American Journal of Agricultural Economics. 61(5):915-920.

Halcyon Ltd. Washington D. C. June, 1990.
Design And Land Use Feasibility Study, Syracuse Harbor, Prepared For Syracuse Industrial Development Agency, City Of Syracuse, State Of New York.

Kay, D. L., T. L. Brown and D. J. Allee. 1987.
The Benefits of the Restoration of Atlantic Salmon to New England Rivers. Ithaca, NY: Cornell Univ. Dept. of Natural Resources, Human Dimensions Research Unit No. 87-6.

Knetsch, J. L. and J. A. Sinden. 1984.
"Willingness to Pay and Compensation Demanded: Experimental Evidence of an Unexpected Disparity in Measures of Value". Quarterly Journal of Economics. August:508 - 521.

Metropolitan/Development Association 1990
"Onondaga Lake Master Development Plan, Meeting Minutes."

Randall, A., B. Ives and C. Eastman. 1974.
"Bidding Games for Valuation of Aesthetic Environmental Improvements". Journal of Environ. Econ. and Manage. 1:132-49.

Randall, A., J. P. Hoehn, and D. Brookshire. 1983.
"Contingent Valuation Surveys for Evaluating Environmental Assets". Natural Resources Journal. 23(3):635-48.

Rowe, R. D., R. C. D'Arge, and D. S. Brookshire. 1980.
"An Experiment on the Economic Value of Visibility". Journal of Environ. Econ. and Manage. 7:1-19.

Samuelson, P. A. 1954.
"Pure Theory of Public Expenditure". Rev. of Econ. and Statis. 36:387-89.

Schulze, W. D., D. S. Brookshire, E. G. Waltham, K. K. MacFarland, M. A.

Syracuse-Onondaga County Planning Agency June 1990.
Onondaga County Plan Report 1, County Growth And Infrastructure .

Syracuse-Onondaga County Planning Agency June 1990.
Onondaga County Plan Report 2. Directory of Governmental Approvals & Permits For Development.

Syracuse-Onondaga County Planning Agency June 1990.
Onondaga County Plan Report 3. Development Goals And Policies. Public Review Draft.

Thayer, R. L. Whitworth, S. Ben-David, W. Malm, and J. Molenar. 1983.
"The Economic Benefits of Preserving Visibilty in the National Parklands of the Southwest". Natural Resources Journal. 23:149-73.

United States Department Of Transportation, Federal Highway Administration. 1990.
Onondaga Lake Bikeway. East-West Link. Draft Design Report.

Sorg, C. and D. S. Brookshire. 1982.
Valuing Increments and Decrements of Wildlife Resources - Further Evidence. Fort Collins, CO: Report to U.S. Forest Service Rocky Mountain Forest and Experiment Station.

Thayer, M. A. 1981.
"Contingent Valuation Techniques for Assessing Environmental Impacts: Further Evidence". Journal of Environ. Econ. and Manage. 8:27-44.

ANNEX C

Onondaga Lake
New York

Environmental
Assessment

ONONDAGA LAKE
City of Syracuse, Onondaga County
New York

Preliminary
Environmental Assessment

U.S. Army Corps of Engineers
Buffalo District

SUMMARY OF ASSESSMENT

Syracuse and Onondaga Lake are located in Onondaga County in central New York approximately 195 miles northwest of New York City, 125 miles west of Albany, 140 and 75 miles east of Buffalo and Rochester, respectively, and 115 miles southwest of the Adirondack Region. Reference EA Figures 1 and 2. Syracuse is a major metropolitan area in New York State with a population (for Onondaga County) of about 464,000. In part, because of its centralized location, Syracuse has developed commercially and industrially. Onondaga Lake and its tributaries have been greatly impacted by both domestic and industrial waste that accompanied the development of the Syracuse area since the late 1800s. Water and sediment quality pollution problems include those pertaining to: ammonia, phosphorous, sodium, calcium, chloride, metals (zinc, lead, copper, chromium, cadmium, mercury, iron), chlorobenzene, fecal coliform, high turbidity, altered nearshore sediments (i.e., calcium carbonate, phosphorous, mercury, etc.), and resultant associated system processes. Like many of the older industrial and commercial cities in the northeast, Syracuse is undergoing redevelopment, however, with increased emphasis on environmental, recreation, and quality of life parameters. The clean-up of Onondaga Lake, polluted over the years by municipal and industrial wastes, has become a focal point of these redevelopment efforts and is expected to serve as an example and asset to community redevelopment efforts.

The Buffalo District is investigating public concerns and potential measures for addressing these concerns. Initially, a wide spectrum of both non-structural and structural measures are considered. They are examined alone and in combination for their: engineering and economic feasibility, environmental and social acceptability, and/or overall ability to meet identified planning objectives.

In order to characterize the resource base of the project area and to facilitate project assessment, information has been obtained from existing literature and coordination with those Federal, State, and local agencies charged with administering fish and wildlife resources, environment and land use plans, and cultural resources.

Needed clean-up measures pertain primarily to control at pollution sources, clean-up of water quality, and clean-up of sediment quality.

Measures developed and evaluated for this technical report include: dredging and disposal of contaminated sediments from Onondaga Lake, development of associated confined disposal facilities (CDF's), solidification of contaminated sediments in CDF, in Lake capping of contaminated sediment, in-Lake water treatment (aeration of the hypolimnion, chemical treatment), and control of major non-point sources of pollution (Onondaga Creek mud-boil diversion and settling basin facility). These were evaluated for preliminary engineering and economic feasibility and general environmental and social acceptability.

Additional measures developed by others were also evaluated to some degree for this technical report and included: metro sewage treatment plant improvement, combined sewer overflow (CSO) treatment and/or diversion, and centralized CSO transmission and treatment facilities. These were evaluated for preliminary engineering and economic and water quality related feasibility, and very generally in this environmental assessment for environmental and social acceptability.

In addition to Onondaga Lake clean-up measures, some potential community and regional development, and natural environmental development environmental enhancement measure considerations were developed. Community and regional development environmental enhancement measures are generally those developed by local and regional planning agencies pertaining to activities and developments such as: aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access, museums, restaurants, etc. Natural environmental enhancement measures were developed in coordination with the U.S. Fish and Wildlife Service and the New York State Department of Environmental Conservation and others pertaining to improvements such as water quality, aquatic and fishery habitat, and wetland development. See the Alternative Considerations section of the Environmental Assessment.

Summary Tables A and B indicate preliminary considered measures estimated costs and generally anticipated impacts relative to environmental evaluation parameters. Summary Table C indicates preliminary coordination compliance relative to various environmental legislation, statutes, executive orders, etc.

Clean-up measures correspond to various levels of clean-up ranging from control of pollution sources, to clean-up of water quality, to clean-up of Lake and tributary sediments. Generally, the higher the level of clean-up, the higher the level of cost and potential short-term implementation concerns (i.e., resuspension of polluted sediments during dredging and disposal operations). However, the higher the level of clean-up also corresponds to higher levels of long-term benefits in terms of potential (safe) environments, activities, and associated developments (i.e., aesthetics, parks, swimming, beaches, boating, marinas and services, fisheries, fishing and access, museums, restaurants, etc.). Reference Summary Table D.

Major environmental work that would need to be completed if any of the formulated measures were to be considered for construction would likely include: continued environmental coordination and plan formulation; preparation of a more detailed environmental impact statement; coordination for a U.S. Fish and Wildlife Service - Coordination Act Report; preparation of a Clean Water Act Section 404 Public Notice and Evaluation Report, if necessary; further cultural resources investigation, assessment, and mitigation, if necessary; and associated report coordination.

Summary Table A

Cost Estimate Summary of Measures, Onondaga Lake

Cost Estimate Summary of Measures

Measure Definition	.c .l First Cost $
1. Dredging of Onondaga Lake	
a. 6,500,000 Cubic Yards	61,700,000
b. 3,000,000 Cubic Yards	28,500,000
c. 2,000,000 Cubic Yards	19,100,000
1.1 Confined Disposal Facilities (Integral with dredging)	
a. Design 1 (Confine 6.5 million CY in 22' of water)	63,500,000
b. Design 2 (Confine 6.5 million CY in 6' of water)	50,700,000
c. Design 3 (Confine 3 million CY)	20,700,000
d. Design 4 (Confine 2 million CY)	17,500,000
1.2 Solidification of Contaminated Sediments ($80/CY) (Integral with dredging)	
a. 6,500,000 Cubic Yards	520,000,000
b. 3,000,000 Cubic Yards	240,000,000
c. 2,000,000 Cubic Yards	160,000,000
2. Capping of Contaminated Sediments (0.5 feet sand)	
a. < 1 ppm mercury	198,000,000
b. < 5 ppm mercury	162,000,000
c. < 10 ppm mercury	143,000,000
3. In-lake Treatment	
a. Aeration of the Hypolimnion	1,378,000
b. Chemical Treatment	12,000,000
4. Non-point Sources	
a. Mud Boils on Onondaga Creek	348,000
b. Waste Beds	N/A
5. Natural Development	10,000 - 400,000
6. Metro Sewage Treatment Plant	
a. Pump Station Upgrading and/or Expansion	N/A
b. Phosphorus, Ammonia, & Nitrogen Removal	N/A
c. Effluent Discharge Alternative	N/A
7. CSO Treatment or Diversion	
a. Best Management Plan	N/A
b. Regional CSO Treatment Facilities	
o Separation of Combined Sewer Systems	N/A
o Storage options	N/A
c. Centralized Treatment & Storage	
o High Rate Treatment Facilities	N/A
o In-water Contaminant Structures	N/A
o In-line Tunnel Storage	N/A

Summary Table B - Generally Anticipated Impacts

Evaluation Parameters	No Action	Dredging, CDF-Disposal, Solidification	Capping of Contaminated Sediments	In-Lake Treatment Aeration Chemical	Non-Point Sources Onondaga Creek Settling Basin	Other Measures Pollution Control
		Measures				
Human (Man-Made) Environment						
Community &	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
Regional Growth	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Displacement	ST:Minor Adverse	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse
of People	LT:Minor Adverse	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Minor Adverse	LT:Not Significant
Displacement	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Minor Adverse	ST:Not Significant
of Farms	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Minor Adverse	LT:Not Significant
Business/Industry	ST:Minor Adverse	ST:Minor Beneficial	ST:Minor Beneficial	ST:Minor Beneficial	ST:Minor Beneficial	ST:Minor Beneficial
Employment/Income	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Recreation	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant
	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Public Facilities	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Moderate Beneficial
and Services	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial
Property Values	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
and Tax Revenue	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial	LT:Minor Beneficial
Noise and	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
Aesthetics	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial	LT:Minor Beneficial
Community	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
Cohesion	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Cultural Resources	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse
	LT:Minor Beneficial	LT:Minor Beneficial	LT:Minor Beneficial	LT:Not Significant	LT:Minor Beneficial	LT:Minor Beneficial
Natural Environment						
Air Quality	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Not Significant	ST:Moderate Adverse	ST:Not Significant
	LT:Not Significant	LT:Moderate Adverse	LT:Not Significant	LT:Not Significant	LT:Moderate Adverse	LT:Not Significant
Water Quality	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Major Beneficial	ST:Moderate Adverse	ST:Moderate Beneficial
	LT:Moderate Benefical	LT:Major Beneficial	LT:Major Beneficial	LT:Major Beneficial	LT:Moderate Adverse	LT:Moderate Beneficial
Plankton	ST:Not Significant	ST:Moderate Adverse	ST:Minor Adverse	ST:Moderate Beneficial	ST:Moderate Beneficial	ST:Moderate Beneficial
	LT:Not Significant	LT:Moderate Beneficial	LT:Minor Adverse	LT:Moderate Beneficial	LT:Moderate Adverse	LT:Moderate Beneficial
Benthos	ST:Not Significant	ST:Moderate Adverse	ST:Major Adverse	ST:Minor Adverse	ST:Moderate Adverse	ST:Major Beneficial
	LT:Not Significant	LT:Major Beneficial	LT:Major Beneficial	LT:Moderate Beneficial	LT:Moderate Adverse	LT:Major Beneficial
Fisheries	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Minor Adverse	ST:Moderate Adverse	ST:Moderate Beneficial
	LT:Not Significant	LT:Moderate Beneficial	LT:Major Beneficial	LT:Major Beneficial	LT:Major Beneficial	LT:Major Beneficial
Vegetation	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse
	LT:Not Significant	LT:Not Significant	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Adverse	LT:Moderate Beneficial
Wildlife	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Minor Beneficial	ST:Moderate Adverse	ST:Minor Beneficial
	LT:Not Significant	LT:Moderate Beneficial	LT:major Beneficial	LT:Moderae Beneficial	LT:Moderate Adverse	LT:Not Significant
Threatened &	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant
Endangered Species	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant
Wetlands	ST:Not Significant	ST:Minor Adverse	ST:Moderate Adverse	ST:Not Significant	ST:Not Significant	ST:Not Significant
	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant

Summary Table C - Relationship of Study to Environmental Protection Statutes and Other Environmental Requirements

Federal Statutes	Study
Archeological and Historic Preservation Act, as amended, 16 USC 469, et seq.	Full
National Historic Preservation Act, as amended, 16 USC 470a, et seq.	Full
Clean Air Act, as amended, 42 USC 7401, et seq.	Full
Clean Water Act, as amended (Federal Water Pollution Control Act), 33 USC 1251, et seq.	Full
National Environmental Policy Act, as amended, 42 USC 4321, et seq.	Full
Rivers and Harbors Act, 33 USC 401, et seq.	Full
Fish and Wildlife Coordination Act, as amended, USC 661, et seq.	Full
Endangered Species Act, as amended, 16 USC 1531, et seq.	Full
Coastal Zone Management Act, as amended, 16 USC 1451, et seq.	N/A
Wild and Scenic River Act, as amended, 16 USC 1271, et seq.	N/A
Federal Water Project Recreation Act, as amended, 16 USC 460-1(12), et seq.	Full
Land and Water Conservation Fund Act, as amended, 16 USC 4601-11, et seq.	Full
Watershed Protection and Flood Prevention Act, 16 USC 1001, et seq.	Full
Farmland Protection Policy Act, (7 USC 4201) et seq.	Full
Executive Orders, Memoranda, Etc.	
Protection and Enhancement of the Cultural Environment (EO 11593)	Full
Protection and Wetlands (EO 11990)	Full
Flood Plain Management (EO 11988)	N/A
Analysis of Impacts on Prime and Unique Farmlands (CEQ memorandum, 30 Aug. 76)	Full
New York State Freshwater Wetlands Act (Wetlands >12.4 acres)	Full
Environmental Conservation Law - Article 15 (Protection of Water)	Full
Local Land Use Plans (See Flood Plain Management EO 11988, also)	Full

The compliance categories used in this table were assigned based on the following definitions:

a. Full Compliance - All requirements of the statue, EO, or other policy and related regulations have been met by this stage of the study.

b. Partial Compliance - Some requirements of the statue, EO, or other policy and related regulations, normally met by this stage of planning, remain to be met.

c. Noncompliance - None of the requirements of the statute, or other policy and related regulations have been met.

d. N/A - The statue, EO or other policy and related regulations are not applicable for this study.

Summary Table D - Clean-Up Levels

Considered Measures	Level of Clean-Up: Pollution Source (Water Quality) — Associated Development Potential: Aesthetics/Park & Facilities; Boating/Marinas; Swimming (Lake Only); Fishing (Water Quality Only) — Associated Benefits (Evaluation Param.)	Water Quality — Associated Development Potential: Aesthetics/Park & Facilities; Boating/Marinas; Swimming (Lake Only); Fishing (Water Quality Only) — Associated Benefits (Evaluation Param.)	Sediment Quality — Associated Development Potential: Aesthetics/Park & Facilities; Boating/Marinas; Swimming (Lake & Beach); Fishery & Fishing (Littoral Zone) — Associated Benefits (Evaluation Param.)
1. No Action	*	*	
2. Dredging CDF-Disposal Solidification		*	*
3. Capping of Contaminated Sediments		*	*
4. In-Lake Treatment °Aeration °Chemical		*	
5. Non-Point Sources Onondaga Creek Settling Basin	*	*	
6. Other Measures Pollution Control	*	*	

Preliminary
Environmental Assessment

Table of Contents

Summary of Assessment

Number	Sections	Page
1	Environmental Setting	1
2	Need for Study and Objectives	33
3	Measure Considerations	41
4	Environmental Effects	56
5	Environmental Coordination & Compliance	80

Appendices

A.	References	
B.	U.S. Fish and Wildlife Service - Planning Aid Letter	
C.	Environmental Correspondence	

SECTION 1 - ENVIRONMENTAL SETTING

INTRODUCTION

1.01 This section provides an overview of the environmental setting in the vicinity of the potential project in order to provide a basis for preliminary environmental assessment and evaluation of various alternative measures.

HUMAN ENVIRONMENT (MAN-MADE RESOURCES)

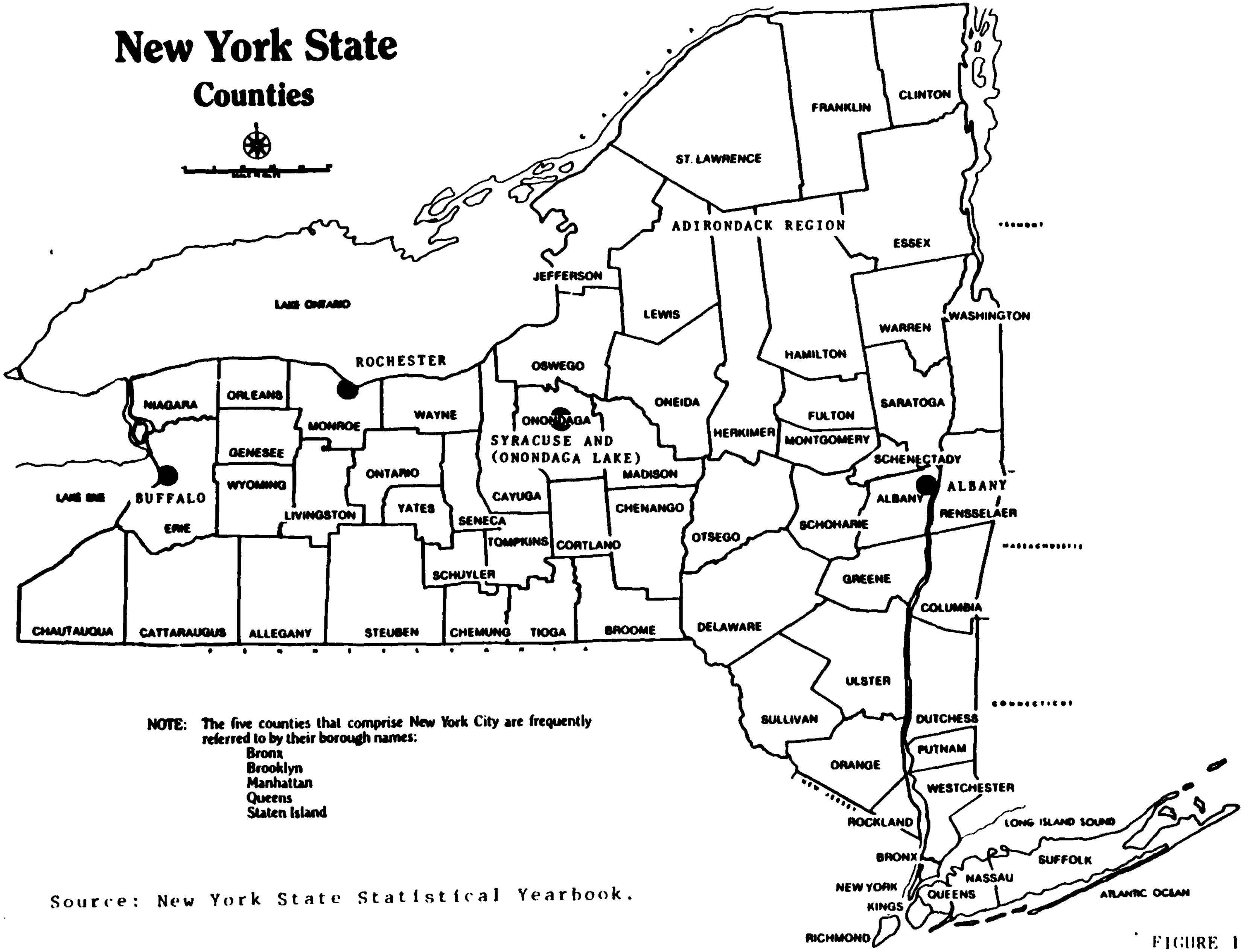
1.02 Community and Regional Growth - Syracuse and Onondaga Lake are located in Onondaga County in central New York approximately 195 miles northwest of New York City, 125 miles west of Albany, 140 and 75 miles east of Buffalo and Rochester, respectively, and 115 miles southwest of the Adirondack Region. Reference Figures 1 and 2. Syracuse is a major metropolitan area in New York State with a population (for Onondaga County) of about 464,000. In part, because of its centralized location, Syracuse has developed commercially and industrially. Like many of the older industrial and commercial cities in the northeast, Syracuse is undergoing redevelopment, however, with increased emphasis on environmental, recreation, and quality of life parameters. The clean-up of Onondaga Lake, polluted over the years by municipal and industrial wastes, has become a focal point of these redevelopment efforts and is expected to serve as an example and asset to community redevelopment efforts.

1.03 Brief History - Onondaga Lake was the Council Fire site for the Iroquois Nation, figured in the Revolutionary War, was settled in post-Revolutionary War times, and saw a salt industry develop along its southeastern shore. As time passed, the Erie Canal was built, the Lake level was lowered, the city of Syracuse was chartered, recreational and commercial development accelerated, and the Industrial Revolution occurred. Soon raw sewage was being discharged to the lake, industrial waste was discharged to the Lake, and higher water uses were lost. World War I accelerated industrial activity. Planning, park, and reclamation activities surfaced. Then with World War II, production became a priority.

1.04 Gross pollution and the loss of recreational, fishery, and aesthetic values were the inevitable result. Postwar pollution abatement programs were developed, Federal environmental activity expanded in the 70s, and a metro treatment plant was built. Rehabilitation efforts continue to this day fueled by public interest, environmental concerns, lakeshore development, industrial waste shutdown, and the Oil City-Carousel Mall proposed development. (Hennigan 1989).

1.05 Table 1 lists some historic, developmental, pollution related, recreational, and clean-up related events to provide a historic overview of events in the Onondaga Lake vicinity. The symbols preceding the listed event identify the nature of the event for easier specific subject tracking. Reference the following table and key to symbols. (From Hennigan 1989)

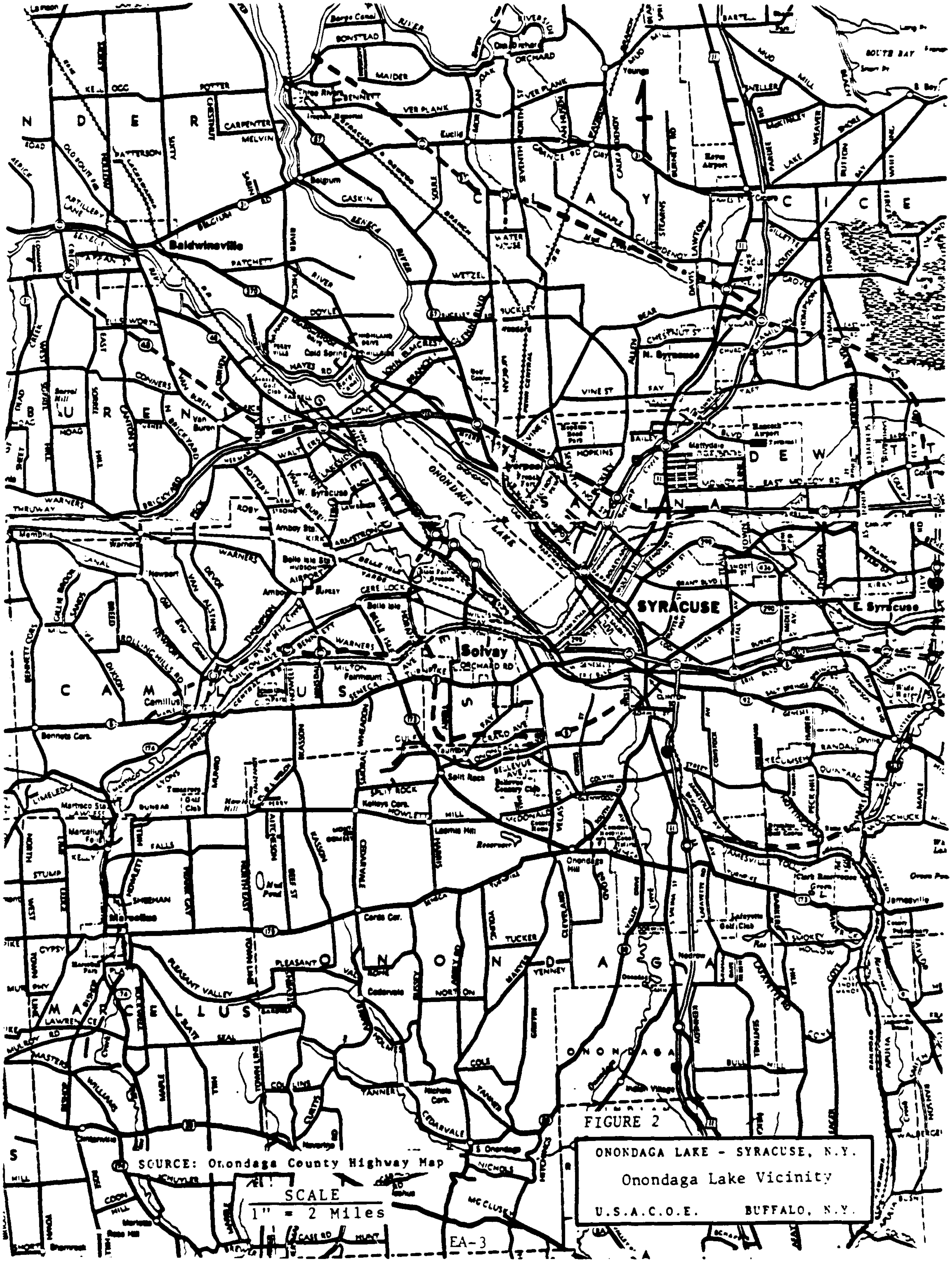
New York State
Counties



NOTE: The five counties that comprise New York City are frequently referred to by their borough names:
- Bronx
- Brooklyn
- Manhattan
- Queens
- Staten Island

Source: New York State Statistical Yearbook.

FIGURE 1



SOURCE: Onondaga County Highway Map

SCALE
1" = 2 Miles

FIGURE 2

ONONDAGA LAKE - SYRACUSE, N.Y.

Onondaga Lake Vicinity

U.S.A.C.O.E. BUFFALO, N.Y.

Key to Symbols

H - Historic

D - Development

P - Pollution Related

PS - Pollution Sewage
PI - Pollution Inorganic Salts
PM - Pollution Heavy Metals
PB - Pollution Benzenes

R - Recreation Related

RR - Recreation Resorts
RS - Recreation Swimming
RF - Recreation Fishing
RP - Recreation Parks

LA - Legislative/Legal Action

Table 1 Development Time Line

Symbols	Date	Event
H,D	1654	Fr. Simon LeMoyne French Jesuit Missionary. Onondaga L. Onondagas. Salt Springs.
H,D	1656	St. Marie De Gannentaha Mission.
H,D	1696	French under DeFronteac defeat the Onondagas.
H,D	1779	Washington sends General Sullivan to fight the Iroquois Nation.
H,D	1783	Revolutionary War ends. Land grants.
H,D	1786	Trading post established at south end of *Onondaga Lake by Ephraim Webster*.
H,D,PI	1788	Fort Stanwik Treaty (Salt Spring Access).
D,PI	1793	Commercial Salt production on Lake.
D,PI	1804	Salt production (100,000 bushels/year).
D	1822	Lake elevation lowered by canal commissioners; drains wetland at south end of Lake.
H,D	1825	Erie Canal Completed.
H,D	1883	First railroads to Syracuse.
H,D	1848	Syracuse Incorporated as a City.
H	1850	Harvey Balwin, first mayor of Syracuse (Onondaga Lake Hanging Garden Speech).
D,PI	1862	Salt production peaks at 9M bushels/year.
H,D,RR	1872	Lake View Point Hotel opens (west shore of Lake)
D,RR	1878	Access road to west shore of lake.
D	1881	Solvay Process Company Formed.
D,PI	1884	Solvay begins soda ash production. Waste residual to nearshore lands at southern end of Lake and Lake itself.

Symbols	Date	Event
D,P1	1887	Solvay process solution mining of salt (-1,500'(+/-) depth) in Tully Valley of Onondaga Creek, 15 miles south of Syracuse.
D,PM,PB	1890	Other major industries - steel, machinery, pottery.
D,RR	1890	Recreational development of west shore continues.
D,PS	1996	Sewers built in city. Sewage flows directly into Onondaga Creek and Harbor Brook.
P,RF	1897	White fish disappears.
D,P	1900	Ice harvesting banned (health).
D	1904	Skaneateles Lake water supply.
P1,LA	1907	State Attorney General threatens legal action. Solvay Process agrees to dump waste residual only on shore and bulkheaded area.
D,PS	1907	Syracuse interceptor sewer board established to clean up Onondaga Creek and Harbor Brook.
D,P1,PB	1918	Solvay Process chlorinated benzene plant. Still bottoms and waste residuals lagooned on site.
P,RR,RS,RF	1920	Recreational use declines due to pollution.
D,P1,PS	1921	City and Solvay Process Company agreement. Company use of point opposite fairgrounds for wastebeds. City disposal of sewage sludge on wastebeds closer to city.
D,PS	1922	Interceptor sewers. Untreated sewage to Lake.
D,PS	1925	Primary sewage treatment plant. Effluent to Lake, sludge to Solvay wastebeds.

Symbols	Date	Event
D,RP	1932-1936	East shore park and parkway built via abandonment of salt production facilities.
P,RS	1940	Swimming banned.
P1,PS	1943	Wastebeds collapse flooding Lakeland neighborhood and fairground with soda ash.
P	1947	State Health Department Study sites seriousness of pollution and recommends attention.
D,P1,PM	1950	Allied (Solvay) chlorine via mercury cell process.
PS	1950	Allied strike leaves city with no sludge disposal. Untreated sewage to Lake. Four years.
P,R	1950	Lake bottoms out. Odorous and unattractive. No swimming or fishing. Sewer and industrial waste.
P,LA	1952	Lake surveyed. Waters classified for fishing and swimming via State water pollution control law.
D,P1	1953	Allied deed 400 acres of wastebeds to State for State Fair parking and highway.
D,PS	1955-	County metropolitan sewer district.
D,PS	1960	New primary treatment plant. Sludge to Allied wastebeds.
P,LA	1968	Federal Study classifies Lake as most polluted body of water in L. Ontario basin.
PM,LA,RF	1970	Mercury discovered in Lake fishery. U.S. Attorney General sues Allied to stop mercury discharge. Fishing prohibited (mercury contamination).
PS	1971-1982	Special Lake studies. Most pertain to sewage effluents.
D,RP	1975	Environmental action plan for lakeshore trail adopted by county. Implementation started.

Symbols	Date	Event
D, PM, PB	1975	Crucible Steel new wastewater treatment and recycling plant.
PI, PM	1976	Mercury production facilities sold by Allied to Lyndon Chemicals and Plastics (LCP).
PB	1977	Allied closes benzene operation.
D, PS	1979	Metro sewage treatment plant expanded to secondary/tertiary treatment. Sludge to Allied wastebeds.
D, PI, PS	1979	Allied wastebed overflows directed to Metro treatment plant to aid in precipitating phosphorous. Problems. 90% (+/-) of waste discharged to Lake.
P, LA	1985-1986	Onondaga Lake management study. Technical analysis (Lake, sewage, industrial waste). Recommends extensive study and temporary State Commission.
PI	1985	Allied announces plans to close down the Solvay operation.
PI, PS	1986	Allied (Solvay) ceases operation and initiates dismantling.
P, LA	1986	Onondaga Lake Commission proposed by County Bill (Lombardi). Governor rejects Commission and proposes an Onondaga Lake Advisory Committee.
P, LA	1986	Onondaga Lake Advisory Committee created by Governor through the Commissioner of DEC.
D, PS	1987	Interceptor sewer best management practices project completed; combined sewer overflows reduced 90%.
P, LA	1987	Onondaga Lake Advisory Committee adopts "Salmon 2000."
D, RP	1987	County Parks initiates Lakeshore extravaganza program. Annual event (July, August).
PM, LA	1988	LCP Corp cited by DEC for mercury releases. Fined. Plant closes.
PS, LA	1988	Atlantic States Legal Foundation complaint against Onondaga County Department of Drainage and Sanitation alleging violation of SPDES permit. Suit joined by Attorney General and Commissioner of DEC.
P, LA	1988	Onondaga Lake Restoration Act introduced (U.S. Senator Moynihan).
D	1988	City of Syracuse and Pyramid Co. announces major lakeshore redevelopment to transform southern shoreline and terminal area to commercial and residential.
H, D, RP	1988	County Parks announces St. Marie redevelopment project (east side of Lake).
D, RP	1988	County Parks contract to finish design of Lakeshore trail.
PS, LA	1989	Judgement on Onondaga County case with abatement schedule.
D, PS	1989	County contract for Liverpool and Ley Creek pump station raw sewage overflows.
P, LA	1989	Governor Cuomo's State of the State message. Restoration of Lake by 2000.
P, LA	1989	Onondaga Lake Restoration Act of 1989 introduced (U.S. Senator Moynihan). Hearings held in Syracuse.
P, LA	1989	State Attorney General and DEC Commissioner complaint against Allied-Signal Corp. for pollution violations and resource damage.
P, LA	1989	Onondaga Lake Advisory Committee "Salmon 2000" conference.
P, LA	1989	Congressional appropriations bill. EPA to create a management conference. COE to begin planning effort.

(Hennigan 1989)

1.06 The following paragraphs also pertain to community and regional growth.

1.07 <u>Population</u> - The population in the Onondaga Lake watershed is about 450,000. Table 2 depicts existing and anticipated population figures for Onondaga County, the city of Syracuse, the towns of Salina and Geddes, and the village of Solvay which encompass the Lake. Reference Figures 1, 2, and 3.

Table 2 - Population

Place	1980	1990	▲	2000	▲	2010	▲
Onondaga Co.	463,920	463,801	-	473,814	+	482,729	+
Syracuse (C)	170,105	160,950	-	159,300	-	158,950	-
Salina (T)	37,400	35,650	-	35,300	-	35,050	-
Geddes (T)	18,528	18,000	-	17,600	-	17,650	+
Solvay (V)	7,140	6,900	-	6,750	-	6,600	-

SOURCE: Population Projection, September 1985, NYS-Water Quality Management Plan, NYS - Department of Environmental Conservation.

1.08 Generally, the population in Onondaga County is 91 percent white and 9 percent black and other. There are approximately 90 males for every 100 females. Approximately 21 percent of the population are 0 to 14 years old, 35 percent are 15 to 34 years old, 32 percent are 35 to 64 years old, and 12 percent are 65 years old or older.

1.09 Generally, moderate population growth is anticipated for the vicinity in the future.

1.10 <u>Land Use and Development</u> - The Onondaga Lake watershed is approximately 240 square miles in area and lies almost entirely within Onondaga County, New York. Current land use within the watershed is approximately 33 percent cropland, 28 percent urban, 22 percent woodland, and 17 percent open and special uses.

1.11 Onondaga Lake is approximately 4.5 square miles in area (about 4.5 miles long and up to a mile wide) and up to 65 feet deep. Major tributaries and their percentage inflows include: Ninemile Creek at 38 percent (Source: Otisco Lake), Onondaga Creek at 34 percent, Metro Sewage Treatment plant at 17 percent, Ley Creek at 8 percent, and Harbor Brook at 3 percent. Reference Figure 4.

1.12 The Ninemile Creek watershed is about 323 square kilometers which is primarily rural agricultural in the upper

SOURCE: Onondaga County Highway Map

FIGURE 3

ONONDAGA LAKE - SYRACUSE, N.Y.
Onondaga Lake Vicinity
U.S.A.C.O.E. BUFFALO, N.Y.

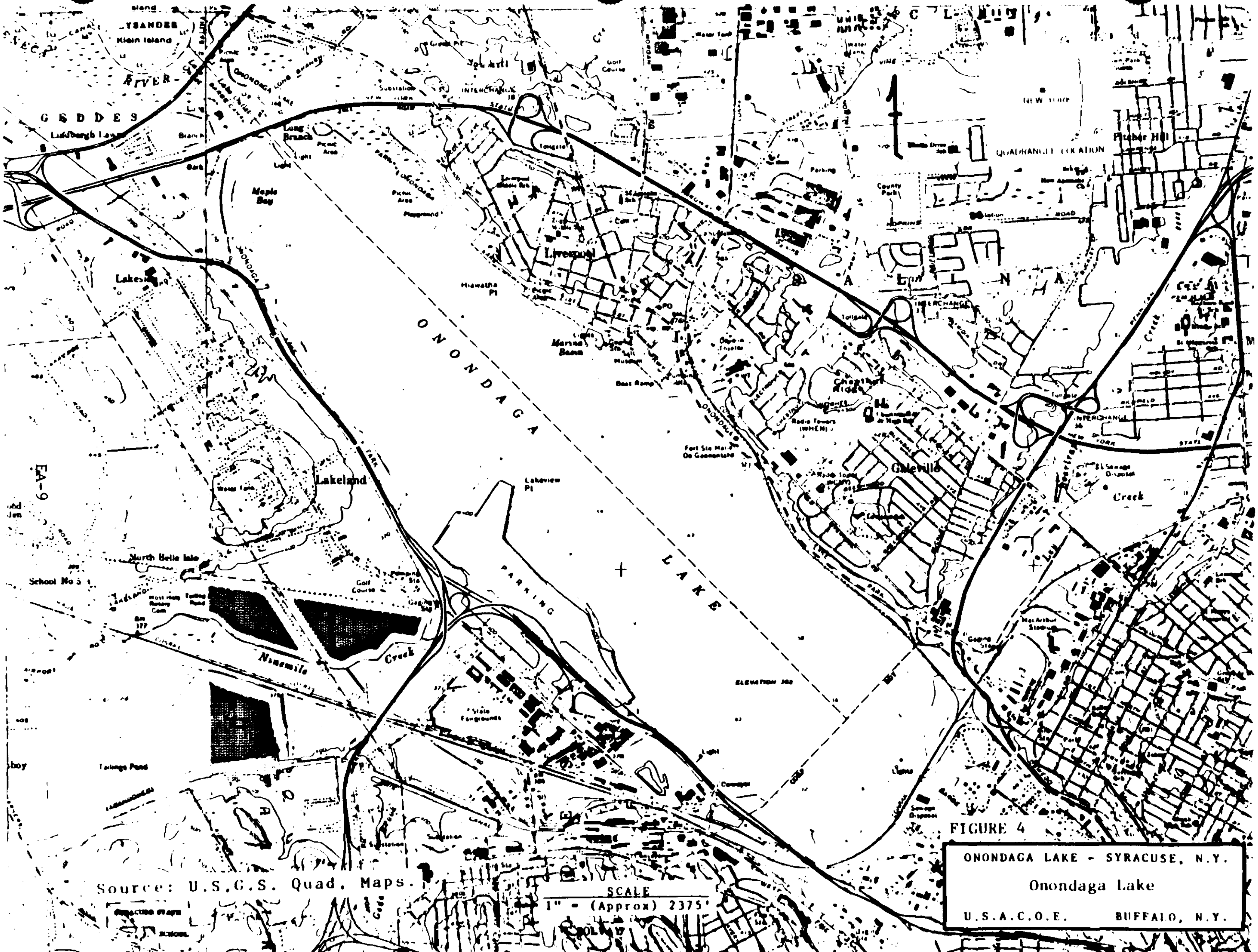


FIGURE 4

ONONDAGA LAKE - SYRACUSE, N.Y.

Onondaga Lake

U.S.A.C.O.E. BUFFALO, N.Y.

watershed (beginning at Otisco Lake) and urban, industrial, and commercial at the outlet. The Onondaga Creek watershed is about 298 square kilometers which encompasses much of the city of Syracuse and extends south into the Tully Valley. The Ley Creek watershed is about 77.4 square kilometers which is primarily residential and industrial with some agricultural. The Harbor Brook watershed is about 29.3 square kilometers, the upper part of which is primarily agricultural, with some urban run-off in the lower reaches.

1.13 The Onondaga Lake shoreline is approximately 12.2 miles long. Reference Figure 4. About 9.5 miles or 78 percent is publicly owned, primarily by Onondaga County with a small amount owned by the city of Syracuse. About 2.7 miles or 22 percent is in private ownership, primarily by Conrail, Allied-Signal Corporation, Crucible Steel, and Niagara Mohawk Power Corporation.

1.14 The county owned property is primarily perimeter parkland located along the northwest, north, and northeast perimeter of the lake. Developments include a hiking/biking path (eventually to perimeter the lake), a marina, a salt manufacturing museum, picnic areas, play grounds, and ballfields. The city owned property is primarily commercial and industrial development, but redeveloping to mixed development, located along the southwest, south, and southeast perimeter of the lake. The private property is primarily industrial development located along the southeast, south, and southwest perimeter of the lake.

1.15 The State Fairgrounds is also located in this latter vicinity. Parking is located on an old industrial soda ash disposal area. Immediate perimeter upland developments are primarily transportation and mixed urban developments. Syracuse proper is located just south of Onondaga Lake.

1.16 Several redevelopment projects are underway in the Onondaga Lake vicinity. On the south end of the lake, the Carousel Mall WAS completed in the fall of 1990. Other mixed developments, primarily commercial, residential, and recreational are being considered to replace primarily old oil storage and warehouse (Canal System) terminal developments no longer utilized. Residential and commercial development in Franklin Square, primarily an old warehouse district, is underway. The St. Marie De Cannentaha Living History Site - formally the site of a 1656 era French Jesuit mission and fort - on the northwestern shore of Onondaga Lake is undergoing renovation.

1.17 Other potential developments being considered for the future include: a beach development, expanded marina, an aquarium, restaurant/dining area, visitors center, performing arts center, theme park, and Oil City marina. Reference Figure 5.

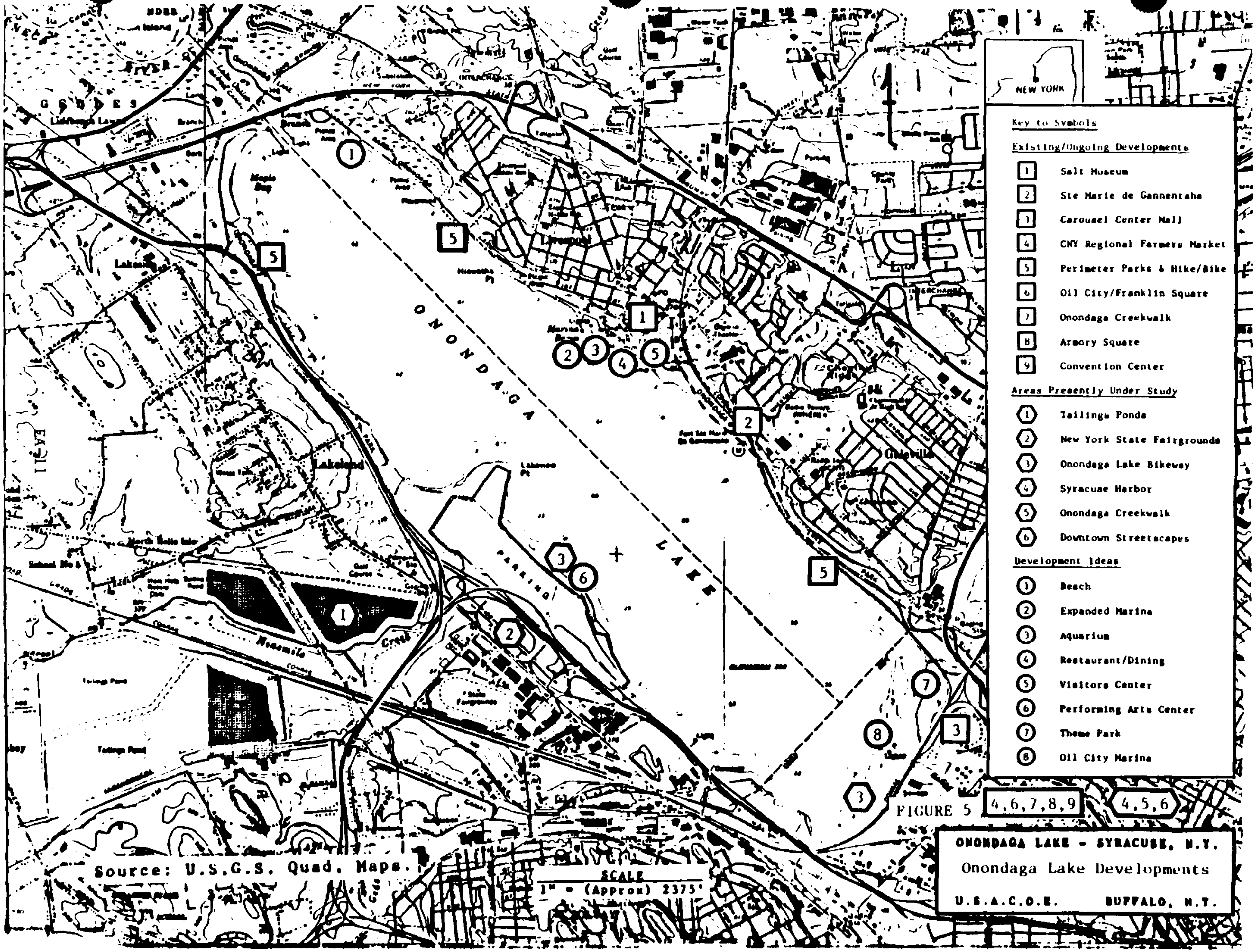


FIGURE 5

ONONDAGA LAKE - SYRACUSE, N.Y.
Onondaga Lake Developments
U.S.A.C.O.E. BUFFALO, N.Y.

1.18 Business, Employment, Income - In 1987, there were some 10,325 business establishments in the Onondaga County area. Most of these establishments pertained to wholesale and retail businesses (35%), and service businesses (34%), followed by: construction (12%), transportation, public utilities, finance, insurance, and real estate (11%), and manufacturing (6%).

1.19 In 1987, of the 235,900 labor force (covered by unemployment insurance) in Onondaga County, approximately 95 percent were employed. The leading employment sectors included: service industries (28%), manufacturing (22%), and retail trade (20%); followed by finance, insurance, real estate (9%), wholesale trade (8%), transportation, communication, public utilities (7%), other (6%), and construction (5%).

1.20 Leading manufacturing employment sectors (1986) in the Syracuse and Onondaga County vicinity include: electric and electronic machinery, machinery, transportation equipment, food and kindred products, printing and publishing, other, chemicals and allied products, primary metals, and instruments.

1.21 The 1986 per capita income for the Onondaga County vicinity was $15,129.

1.22 Generally, moderate growth in business, employment, and income is anticipated for the area.

1.23 Recreation - Approximately 42 percent of the 12-mile lake perimeter is parkland developed by Onondaga County. Reference Figure 4. This is primarily located along the northwest, north, and northeast perimeter of the lake. Developments include a hiking/biking path (eventually to perimeter the lake), an 80 slip marina with ramp, a salt manufacturing museum, picnic areas, playgrounds, and ballfields.

1.24 With continued community and industrial developments and associated pollution, primarily in the late 1800's and early 1900's, water and sediment quality degraded in the lake until swimming was banned (≈ 1940) and consumption of fish from the lake was not recommended. Although measures have been taken to improve water quality and to some degree sediment quality, swimming is still banned and consumption of fish from the lake is still ill advised today.

1.25 The primary exceeded parameters resulting in the swimming ban are: high turbidity (transparency is generally less than 4 feet) due primarily to high concentrations of phytoplankton, calcium carbonate, and clays; and frequently violated fecal coliform standards following high runoff events, primarily as a result of combined sewer overflows. Additional concerns pertain to pollution of water and sediments with pollutants for which there may be no established "safe for swimming" standards.

1.26 Fish consumption advisories pertain primarily to potential bio-accumulation of mercury.

1.27 The demand for recreational development of the lake is particularly strong since the lake is located at the northern boundary of the city of Syracuse, a significant urban area of New York State. The New York State Comprehensive Recreation Plan (1983) identified the following activities as high regional demand activities for which facilities development is of high demand. Activities include: swimming, boating, picnicking, hiking/biking, and tennis. The potential for development of some of these facilities around Onondaga Lake to meet these demands is high, particularly if water and sediment quality problems can be reduced.

1.28 The Onondaga Lake Park is very popular. In addition to normal park operations, special events include: annual hydroplane races, the Intercollegiate Rowing Association regatta, and the county parks' waterfront extravaganza.

1.29 Public Facilities and Services.

1.30 Water - Communities in the project vicinity generally obtain their community water supplies through the Onondaga County Water Authority who in turn obtain their water supply from the Metropolitan Water Board. The primary source of water is Lake Ontario. Supplemental sources of water include: Otisco Lake, Skaneateles Lake, and Ray Dam.

1.31 Sewage Disposal - The U.S. Environmental Protection Agency (USEPA) and the New York State Department of Environmental Conservation (NYSDEC) are primarily responsible for permitting and monitoring point source effluent discharges to New York State waters. The Syracuse Metro Sewage Treatment Plan is now a tertiary treatment plant with a design flow of about 80 million gallons per day which discharges into Onondaga Lake. Additionally, the system has gone to a best management plan (BMP) which has eliminated most of the combined sewer overflow pollution problems which periodically occurred when storm sewer run-off combined with sewage allowing some sewage to bypass the sewer treatment process. Some special or additional treatment measures and facilities however, may still need to be considered to address associated pollution problems to Onondaga Lake. USEPA, NYSDEC, Onondaga County, and the city of Syracuse are working to investigate these additional needs.

1.32 Tributaries which flow into Onondaga Lake receive urban and rural run-off and point source effluent discharges from municipal and industrial sources. Ninemile Creek receives treated wastewater from the village of Camillus and Marcelles and overflow and infiltration from the wastebeds of Allied Chemical Corporation. Fifty-three combined sewer overflows discharge to

Onondaga Creek. Two combined sewer overflows enter Ley Creek, as well as two sewer overflows at the Brooklawn and Ley Creek pump stations. Harbor Brook receives discharge from 20 combined sewer overflows of the Hillcrest and Brookside pump stations. Tributary 5A receives treated wastewater from Crucible Steel. Bloody Brook receives no significant pollutant point sources with the exception of some treated coolant and wastewater from the General Electric Corporation's Park complex. Sawmill Creek receives no significant pollutant point sources.

1.33 Utilities - The project area is located in close proximity to the city of Syracuse and utility services including: water, sewer, gas, electric, and telephone are readily available.

1.34 Transportation - Onondaga Lake is a branch from the Seneca River-Barge Canal portion of the New York State Barge Canal system to Syracuse. The system now services primarily recreational vessels. A maintenance office and terminal is still located at the southeastern end of the lake along Onondaga Creek.

1.35 Syracuse, being located in central New York State, has historically served as an interchange location, first for the Barge Canal, and presently for the New York State Thruway System, which generally closely parallels the major routes of the old Barge Canal system. Major thoroughfares closely perimeter Onondaga Lake with Routes 90 and 81 to the north and east, and Route 690 to the south and west. Syracuse proper is located immediately south of Onondaga Lake. Local access roads perimeter the lake. Reference Figure 2.

1.36 Police and Fire Protection - The project vicinity is serviced by local village, town, and city police. These services are also supplemented by the county sheriffs department and New York State Police. Similarly, the project vicinity is serviced by local village, town, and city fire departments.

1.37 Property Value and Tax Revenue - The average value of farmland (land and buildings) for Onondaga County is roughly estimated at $1,614 per acre. The median value of occupied housing units in Onondaga County is roughly estimated at $69,480. Onondaga Lake is situated in close proximity to the city of Syracuse in Onondaga County. Property values may vary greatly depending on site, demand, aesthetics, etc. Local tax revenues generally include revenue sharing (Federal, State, Local), and local property, service district, and sales taxes.

1.38 The Onondaga Lake vicinity is undergoing redevelopment with increasing property values and associated tax revenues. Most of the immediate Lake perimeter property will remain County owned.

1.39 Noise and Aesthetics - The major source of noise in the project vicinity is generated from the movement of vehicular traffic along the major thoroughfares. Noise was also noted from the operation of construction vehicles and equipment in the redevelopment construction areas in the Syracuse vicinity at the southeast end of the Lake. Some industrial noise was also noted along the industrial developed southwest perimeter portion of the Lake.

1.40 The Lake vicinity provides a varied assortment of aesthetic experiences depending on location ranging from views to industrial waste sites, to urban redevelopment, to park views of a marina and boats on the Lake. A close look to the Lake itself is almost mystic with its milkish color, and sediment coating of calcium carbonate and associated precipitate pebbles. The park areas, primarily along the northwest, north, and northeast shoreline are very pleasing in a generally urban vicinity setting.

1.41 Community Cohesion - The project vicinity has long been developed and has a long history of changing developments from the Iroquois Indians, to the Revolutionary War, to salt production, to the barge canal, to the resort era, to the industrial revolution, to environmental consciousness. Most persons concur that Onondaga Lake should be cleaned up to an acceptable level, and that it could prove to be a valuable asset to the community.

CULTURAL RESOURCES

1.42 Cultural Resources - The Onondaga Lake vicinity has a long and interesting history of activity and development. Reference the paragraphs following Community and Regional Growth page 1. Coordination with the New York State Office of Parks, Recreation, and Historic Preservation - State Historic Preservation Officer (SHPO) indicates that the Onondaga Lake vicinity is known to contain numerous prehistoric and historic archeological sites and historic sites.

NATURAL ENVIRONMENT (RESOURCES)

General.

1.43 Based on known existing available information, this section provides preliminary background data on environmental conditions in the general vicinity of Onondaga Lake and its tributaries for the following parameters: air quality, water quality, plankton, benthos, fisheries, vegetation, wildlife, and threatened or endangered species. References utilized are identified in the narrative as well as in the bibliography which is included with this environmental assessment document.

1.44 Air Quality - A review of the document entitled "New York State Air Quality Report - Ambient Air Monitoring System" (NYSDEC, 1988) indicates that at air monitoring sites in Onondaga County, air quality is in compliance with Federal and State standards for sulfur dioxide (SO_2), total suspended particulates (TSP), carbon monoxide (CO), inhalable particulates (PM_{10}), lead (Pb), and ozone. This means that these air quality parameters are not in contravention (exceedance) of the following established Federal (F) and State (NYS) ambient air quality standards: 0.03 parts per million (ppm) for SO_2 (F and NYS); 260 micrograms per cubic meter (ug/m^3 (F) and 250 ug/m^3 (NYS) for TSP; 150 ug/m^3 for PM_{10}; 35 ppm for CO (F and NYS); 1.5 ug/m^3 for Pb (F and NYS); and .12 ppm (NYS) and 235 ug/m^3 (F) for ozone.

1.45 Onondaga County is located within the Central Air Quality Control Region of New York State. This region contains eight other counties within its boundaries. The air quality data summary for this region outlined in the aforementioned NYSDEC report indicates that, the regional average for each air quality parameter falls within the Federal and State designated standards. The regional averages are 0.005 for SO_2; 46.9 ug/m^3 for TSP; 31.2 ug/m^3 for PM_{10}; 1.4 ppm for CO; 0.04 ug/m^3 for lead, and 0.030 ppm for ozone.

1.46 Water Quality - Onondaga Lake is an urban lake that is surrounded by commercial, industrial, and residential land use. The Lake is adjacent to the northern boundary of the city of Syracuse, as well as the towns of Geddes and Salina in Onondaga County. The towns of Liverpool and Solvay are located nearby. The Lake is considered to be dimictic because it generally experiences two periods of circulation (overturns) each year. However, "chemical contributions to the density structure of the Lake tend to impede the rate of mixing of Lake waters during overturn" (Onondaga County, 1971). Based on best use, the current NYS water quality classification for Onondaga Lake is Class "B" northwest of a line extending from a point located on the west shore 0.25 miles northwest of the mouth of Tributary 5A, to a point on the east shore located 0.6 miles southeast of the mouth of Bloody Brook. The Lake is designated as being Class "C" southeast of the mouth of Tributary 5A, to a point located on the east shore 0.6 miles southeast of the mouth of Bloody Brook. The Class "B" designation implies potential for bathing and any other uses except as a source of water supply for drinking, culinary, or food processing purposes. A Class "C" designation implies potential for fishing and any other use except for bathing, as a source of water supply for drinking, culinary, or food processing purposes.

1.47 Over the years, the Lake has served as a water supply and receptacle for wastes for municipalities and industries. As a result, the water quality has deteriorated significantly. The discharges of municipal effluents and industrial wastes have left

the Lake polluted and hypereutropic. Onondaga Lake experiences anoxia within its hypolimnion and has a very high algae crop and algal macronutrient content, as well as poor water transparency (Meyer and Effler, 1980). Water transparency in the Lake is generally less than 4 feet due to high concentrations of phytoplankton, calcium carbonate, and clays. The fecal coliform standards are frequently violated following high runoff events, primarily as a result of combined sewer overflows (CSOS), thus prohibiting swimming (Auer, 1989; Auer and Niehaus, 1989; Effler, 1988; Heidtke, 1989). The fishery is impacted by mercury contamination of fish flesh, inadequate dissolved oxygen, and the destruction of fish habitat (Brooks and Effler, 1989; Effler, Brooks, Auer, and Doerr, 1990). Excessive chlorides make the Lake's freshwater unnaturally saline and also prevents the top and bottom waters from mixing, thus keeping the oxygen levels low (Flocke, 1990). The oxygen depletion problem is so severe that adequate concentrations for support of fish life are often limited to the upper 4-5 meters of the water column in the summer. During the fall mixing period, the New York State standard of 4 milligrams per liter for dissolved oxygen is violated because of the oxygen-demanding reduced chemical species accumulated in the bottom waters during the summer (Effler, Hassett, Auer, and Johnson, 1987; Effler, Perkins, and Brooks, 1987). The high phytoplankton concentration occurs because of the phosphorus and nitrogen loadings. Sources of phosphorus include the Metropolitan Sewage Treatment Plant combined sewer overflows, internal recycling from bottom sediments and from nonpoint sources.

1.48 Since 1970, the Onondaga County Department of Drainage and Sanitation has monitored 5 of the natural tributaries to the Lake (Ley Creek, Onondaga Creek, Ninemile Creek, Harbor Brook, and Tributary 5A) as well as the Lake outlet (Stearns and Wheeler, 1990). Sawmill Creek, Bloody Brook, and the Barge Canal have not been monitored over the years, however, available information is provided.

1.49 Ley Creek enters Onondaga Lake about 0.2 miles southeast of a point where the city of Syracuse line intersects the east shore of the Lake. This Creek drains a watershed area of 77.4 square kilometers east of Onondaga Lake. The majority of the watershed is residential and industrial in nature with some in agricultural land. Two combined sewer overflows enter Ley Creek as well as two sanitary sewer overflows at the Brooklawn and Ley Creek pump stations. The concentrations and loads of biological oxygen demand (BOD) and indicator bacteria have varied over the course of the annual monitoring program. The variability may be due to the sanitary landfill or to the timing of the water quality sampling in relation to storm events and operation of the combined sewer overflow network. The current

NYS water quality classification designation for Ley Creek from its mouth upstream to the Ley Creek Sewage Treatment Plant sewer outfall is Class "D" (best usage for agricultural or as a source of industrial cooling or process water supply and any other usage except for fishing, bathing, or as a source of water supply for drinking, culinary, or food processing purposes). From the sewer outfall upstream to the South Branch, Ley Creek is designated as having a classification of "B" (best usage for bathing and any other uses except as a source of water supply for drinking, culinary, or food processing purposes).

1.50 Onondaga Creek, located at the southeastern end of Onondaga Lake, drains a watershed area of about 298 square kilometers. The watershed encompasses much of the city of Syracuse and extends south into the Tully Valley. Fifty-three combined sewer overflows discharge to the Creek. Based upon recent monitoring data, it appears that the water quality of the Creek is degraded with elevated concentrations of fecal coliform bacteria, salts, and the heavy metals, lead, copper, and chromium. Additionally, sources of high sediment load carried by the Creek have been identified in southern Tully Valley. The NYS water quality classification for Onondaga Creek from its mouth upstream to Temple Street in Syracuse is Class "D"; from Temple Street upstream to Tributary 5B the Creek is designated as being Class "B"; from this tributary upstream to the source of Onondaga Creek the classification is "C" (best usage is for fishing and any other use except for bathing, as a source of water supply for drinking, culinary, or food processing purposes.

1.51 Harbor Brook, which enters Onondaga Lake at the southernmost point of the Lake, drains a watershed of about 29.3 square kilometers, extending to the southwest of the Lake. The upper watershed is primarily agricultural and the lower reaches receive urban runoff and discharge from 20 combined sewer overflows of the Hillcrest and Brookside pump stations. Recent monitoring shows the concentration of total inorganic carbon, particulate organic carbon, copper, and lead were elevated. The loads from this source may be underestimated because the county's Lake monitoring program does not sample storm events. The NYS water quality classification for Harbor Brook from its mouth to the upper end of the underground section at Gifford Street in Syracuse is designated as being Class "D"; from this point upstream to the city of Syracuse line the designation is Class "B"; from the City's line to the source of the Brook, the classification is "C".

1.52 Ninemile Creek, which enters Onondaga Lake from the south approximately 2.25 miles from the Lake's outlet along the west shore, has a watershed of about 323 square kilometers and includes Otisco Lake. The Creek receives ionic salts from wastebeds as well as treated wastewater from the villages of Camillus and Marcellus.

1.53 Tributary 5A enters Onondaga Lake about 0.8 miles northwest of the city of Syracuse line and the west shore of the Lake. This tributary receives treated wastewater from crucible steel. Tributary 5A has historically contributed iron, chromium, and copper to the Lake. Prior to 1974, these metals were not treated, however, the construction of an industrial wastewater reuse and treatment plant has resulted in significant reductions in loading.

1.54 The Bloody Brook watershed has an area of about 11.7 square kilometers, which extends to the northeast from about the mid-section of the east shore of Onondaga Lake. This Brook enters Onondaga Lake about 2.25 miles southeast of the Lake's outlet. The tributary receives no significant pollutant point sources with the exception of some treated coolant and wastewaters from the General Electric Corporation's Park complex (Bloomfield, 1979). From its mouth upstream to Tributary 8 (which is located about 0.4 mile from the mouth of the Brook), the NYS water quality classification is Class "B"; beyond Tributary 8 upstream to the Brook's source it is Class "D".

1.55 Sawmill Creek has a very small watershed and receives no significant pollutant point sources. From its mouth upstream to Euclid Road, the Creek has a NYS water quality classification designation of Class "B"; from Euclid Road to the Creek's source it is Class "D".

1.56 With regard to the Onondaga Lake Outlet, the Outlet has not been monitored. The Barge Canal Terminal is actually the downstream reach of Onondaga Creek and the water quality for Onondaga Creek is characteristic of this lower end.

1.57 Plankton - Microscopic algae, referred to as Phytoplankton, annually cause dense blooms in Onondaga Lake that affect the Lake's water clarity as well as its oxygen resources (Onondaga County, 1990). Some idea of phytoplankton as well as zooplankton previously found in the Lake is provided in available literature as follows:

1.58 A publication entitled "Algae, Man and the Environment" (Jackson, 1968) points out that, since about 1962, blooms of algae have been known to occur annually in Onondaga Lake - usually in late June or early July - and that such blooms are composed of members of two Divisions, the Chlorophyta and Euglenophyta. Further, "diatoms are abundant throughout the year" and the algae genera Chlamydomonas and Cyclotella both normally occur in abundance in Onondaga Lake (Jackson, 1968).

1.59 Onondaga County conducted phytoplankton studies between April 1968 and December 1969, during which time about 100 species of algae were identified. At the time of the study, "the dominant phytoplankters show the expected succession for a shallow, nutrient rich Lake: diatoms and flagellates in the spring, green algae of the Chlorococcales in the early summer, blue-green algae in the summer, and an association of diatoms and flagellates in the fall" (Onondaga County, 1971). Reference Figure 6 for sampling stations.

1.60 The results of a 1975-77 monitoring study done in the Lake were described in a paper entitled "Seasonal Succession of Phytoplankton in Onondaga Lake, New York, USA" (Sze, 1980), whereby samples of phytoplankton were taken at 0, 3, 6, and 12 meter depths at a station that was located in the deepest part of the Lake. The pattern of phytoplankton succession in the Lake during the time of sampling was considered to be generally similar to the period 1973-74 after phosphorus was reduced in this water body (Sze, 1975), due to banning of detergents with phosphorus by the State of New York around 1972. There was about an 80 percent decrease in dissolved phosphorus in Onondaga Lake after 1972 (Murphy, 1973). Prior to 1972, chlorococcalean green algae such as Chlorella and Scenedesmus were replaced by blue-green algae - mainly Microcystis and Aphanizomenon - as the dominant mid-summer algal group. Following 1972, throughout the summer period, green algae were dominant, whereas the blue-green algae were almost completely absent (Sze, 1975). During the 1975-77 monitoring study, diatoms and flagellates were commonly found during the spring season, followed by replacement with chlorococcalean green algae as being dominant. Around late September, abundance of algae decreased, but many of the summer algal species still persisted at lower concentrations (Sze, 1980).

1.61 A more recent study of plankton in Onondaga Lake during the period May 27 to October 27, 1987, includes information regarding the abundance of major phytoplankton and zooplankton groups in Onondaga Lake. The plankton study report "Zooplankton Impacts on Chlorophyll and Transparency in Onondaga Lake, New York, USA" (Au, M.T., et al) notes that, during the spring season, the dominant phytoplankton found were cryptomonads (Cryptomonas erosa and Chroomonas sp.), as well as flagellated green algae (Chlamydomonas sp.). Some species of diatoms were

also present (i.e., Cyclotella meneghiniana and Synedra delicatissima). In the spring, zooplankton found in the sampling were Cyclops copepodites and adult Cyclops vernalis and Cyclops bicuspidatus. Following a clearing event that took place on July 13, it was found that the abundance of herbivorous zooplankton dropped - which may have been due to a decrease in abundance of food (Lampert, E., et al, 1986). After the clearing event had occurred in Onondaga Lake, phytoplankton numbers increased, whereby chlorococcalean green algae such as Oocystis parva, Pediastrum duplex, and Coelastrum microporum were dominant. There was a decrease in calanoid copepods and Cladocerans around late August and early September, however, the population of cryptomonads and flagellate green algae increased. Over the remaining 3 month study period after the Lake's clearing event, notable shifts in plankton composition of both phytoplankton and zooplankton occurred (Aur, M.T., et al).

1.62 Existing information on zooplankton studies for Onondaga Lake are limited. However, Onondaga County did conduct zooplankton studies from January to December 1969 in the Lake. Sampling for zooplankton was done by hauling nets vertically and horizontally at the same Lake stations as that for phytoplankton. As summarized in the "Onondaga Lake Study" report (Onondaga County, 1971), "17 species in 10 genera were identified. The dominant forms include 3 rotifers, 1 copepod, and 3 cladocera." The genera or species of rotifers found were Keratella hiemalis, brachionus sp., and Polyarthra sp.; the species of copepods were identified as being mostly Cyclops vernalis; and the species of cladocerans were daphnia similis, Daphnia pulex, and Ceriodaphnia quadrangula. It was concluded that "in general, Onondaga Lake supports a community of zooplankton which is typical for a saline Lake at this latitude."

1.63 A report on the Onondaga Lake Monitoring Program (Onondaga County, 1990) addresses results of a 1988 survey of both phytoplankton and zooplankton in the Lake. During the sampling period between March 30 and November 11 - whereby samples were collected at north and south areas of the Lake - a variety of phytoplankton that included flagellated green algae, non-flagellated green algae, diatoms, euglenoids, dinoflagellates, cryptomonads, and cyanobacteria were identified. Phytoflagellates dominated the Lake during the May-June period, whereas chlorococcalean green algae were dominant in the Lake during the July-October period. The predominant species of phytoplankton noted during the summer sampling was Oocystis parva. The report indicated that "diatoms continued to be a relatively unimportant group." With regard to zooplankton, rotifers, copepods, and cladocerans were found inhabiting Onondaga Lake. The Lake monitoring report indicated that the "rotifers Keratella and Brachionus were common during late April and early May; also that, cladocerans were abundant from May into November." The abundance of zooplankton was determined to be comparable to previous years, according to the report.

1.64 No known current data was available at this time on phytoplankton and zooplankton for the major tributaries to Onondaga Lake.

1.65 Benthos - Available studies on benthic invertebrates in Onondaga Lake and its tributaries are limited. Recently, in 1989, some preliminary study of benthic invertebrates in the Lake was started (Wagner, Ringler, and Effler, unpublished), however, quantitative data on primary as well as secondary producers are lacking (Ringler, et al). Noble and Forney (1971) reported some work done on benthic fauna in Onondaga Lake, whereas Cooper, et al (1974) collected and identified benthic organisms in some areas of Ninemile Creek during a water quality study (Reference Table 3 for station locations). Also, the New York State Department of Environmental Conservation (NYSDEC) conducted a biological survey in 1989, during which macroinvertebrate populations were documented in a number of tribuatary creeks (Reference Table 4).

1.66 As part of the "Fish Survey of Onondaga Lake" - Summer 1969 (Noble and Forney, 1971) conducted sampling for benthic invertebrates at four fishery sampling stations in the Lake - namely stations number 3, 5, 6, and 8 (Reference Figure 6 for station locations). At the time of the survey, no benthic organisms were found at stations number 3 and 6. At station number 8 - located along the west shore of the Lake, near the mouth of Ninemile Creek - it was reported that a large number of benthic organisms were taken, that included chironomid larvae and Ostracod (seed shrimp) at a depth of 6 feet and chironomid larvae at 10 feet of depth.

1.67 A "Macoinvertebrate Study of Ninemile Creek" (Cooper, et al, 1974) was conducted during the week of August 21-24 and again on August 27, 1973 by NYSDEC. Nine stations in riffle zones of the Creek were sampled with a Surber sampler between Otisco Lake, downstream to a point below the waste entry of the Allied Chemical Solvay plant (Reference Table 3). A diversity of benthic fauna were collected. The major groups of benthic macroinvertebrate taxa found during the survey were Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), Diptera (true-flies), Neuroptera (alderflies, fishflies, and hallgramites), Coleoptera (beetles), Mollusca (snails), Isopoda (sow bugs), Amphipoda (freshwater scuds), Oligochaeta (worms), Platyhelminthes (flatworms), Acari (watermites), and Gordian Worms (roundworms). In general, mayflies, caddisflies, beetles, and worms were found at 8 of the 9 creek stations, whereas the true-flies were found at all 9 stations.

1.68 A biological survey that sampled resident macroinvertebrates in tributary streams (creeks and brooks) to Onondaga Lake was conducted on June 2 and June 27, 1989 by the NYSDEC Stream Biomonitoring Unit (Bode, et al, 1989). The waterways sampled included Sawmill Creek, Bloody Brook, Ley

TABLE 3 - LOCATION OF NINEMILE CREEK BIOLOGICAL SAMPLING STATIONS *

Station	
1.	Ninemile Creek on first riffle about 60 feet above Schuyler Road bridge (1st bridge south of U.S. Route 20) near U.S. Geological Gauging Station; mileage point about 20.1 and about Latitude 42° 55' 15" N, Longitude 76° 19' 48" W.
2.	Ninemile Creek on first riffle about 75 feet below bridge on Lawrence Road, the second bridge below U.S. & NY Route 20; mileage point about 15.8 and about Latitude 40° 57' 27" N, Longitude 76° 20' 28" W.
3.	Ninemile Creek at lower end of riffle about 70 feet below bridge on North Street (NY Route 174) just below Marcellus, NY; mileage point about 12.85 and about Latitude 40° 59' 29" N, Longitude 76° 20' 25" W.
4.	Ninemile Creek about 400 feet below first bridge below old Sagamore Paper Plant by small picnic area; mileage point about 11.6 and about Latitude 40° 0' 20" N, Longitude 76° 20' 13" W.
5.	Ninemile Creek on lower section of second riffle about 700 feet above bridge on NY Route 5 in Camillus, just below first tributary from east (dry not shown on map); mileage point about 7.83 and about Latitude 43° 2' 20" N, Longitude 76° 18' 31" W.
6.	Ninemile Creek on second riffle about 800 feet below old Erie Canal crossing; mileage point about 4.75 and Latitude 43° 3' 32" N, Longitude 76° 17' 10" W.
7.	Ninemile Creek on riffle about 500 feet below bridge over NY Route 173 at Amboy (just below Robert B. Spence Co.); mileage point about 3.85, Latitude 43° 4' 11" N, Longitude 76° 16' 25" W.
8.	Ninemile Creek about 60 feet below dirt road bridge and about 1 mile below Amboy; mileage point about 2.95; Latitude 40° 4' 39" N, Longitude 76° 15' 50" W.
9.	Ninemile Creek about 40 feet above bridge on NY Route 48 below Allied Chemical Co.; mileage point about 0.7; Latitude 40° 14' 50" N, Longitude 76° 13' 36" W.

* SOURCE: (Copper, et al, 1974)

TABLE 4 - LOCATIONS, SUBSTRATE AND DOMINANT BENTHIC ORGANISMS AT ONONDAGA LAKE TRIBUTARY SITES SAMPLED DURING THE 1989 NYSDEC SURVEY *

Creek	Station Location	Substrate	Invertebrates
Sawmill Creek	Riffle zone. Upstream of Route 370 bridge adjacent to NYS Thruway	Gravel/Rubble	Riffle Beetle (*Stenelmis crenata*) Sowbug (*Asselus racovitzai*) Caddisfly (*Hydropsyche betteni*)
Bloody Brook	Riffle zone. Adjacent to the Lake-shore Drive-In off Route 370	Rubble	Blackfly (*Simulium vittalum*) Midge (*Cricotopus tremulus*) Midge (*Conchopelopia* sp.)
Ley Creek	Station #1 Swift current Above Lemoyne Bridge at Route 298	Gravel/Rubble	Sowbug (A. *racovitzai*) Midge (*Conchopelopia* sp.) Midge (C. *tremulus*)
	Station #2 Slower current, much less riffle area. Near the USGS gaging station, approx. 0.6 kilometers upstream of the mouth.	------	Worm (*Limnodrilus hoffmeister*) Midge (*Conchapelopia* sp.) Midge (C. *tremulus*)
Onondaga Creek	Station #1 Upstream site in Cardiff	------	Worm (L. *hoffmeisteri*) Mayfly (*Baetis brunneicolor*) Midge (*Tvetenia vitracies*)
	Station #2 Above Spenser St. in Syracuse, NY	Rock/Rubble/ Gravel/Sand	Worm (*Nais elinquis*) Worm (*Enchytraeidae*) Sowbug (A. *racovitzai*)
Harbor Brook	Station #1 Riffle Zone Off Route 173 near town of Split Rock	Rubble/Gravel	Midge (*Cricotopus bicinctus*) Midge (*Micropsectra polita*) Midge (*Eukiefferiella claripennis*)
	Station #2 Near USGS gaging station about 0.8 kilometers upstream of the mouth	Some Rubble and Gravel	Worm (*Nais elinquis*) Worm (*Enchytraeidae*) Worm (*Nais variabilis*)
Geddes Brook (Tributary to Ninemile Creek)	Strong current. Upstream of the Horan Road bridge	------	Worm (N. *elinquis*) Sowbug (A. *racovitzai*) Worm (*Enchytraeidae*)
Ninemile Creek	Station #1 Swift Current. Upstream of Amboy, below Warners Road bridge	Rocks/Rubble/ Gravel	Scud (*Grammarus* sp. Worm (N. *elinquis*) Worm (L. *hoffmeisteri*)
	Station #2 Upstream of State Fair Boulevard	Clay with rubble and gravel pockets	Scud (*Grammarus* sp. Worm (N. *elinquis*) Worm (L. *hoffmeisteri*)

* SOURCE: (Bode, et al. 1989)

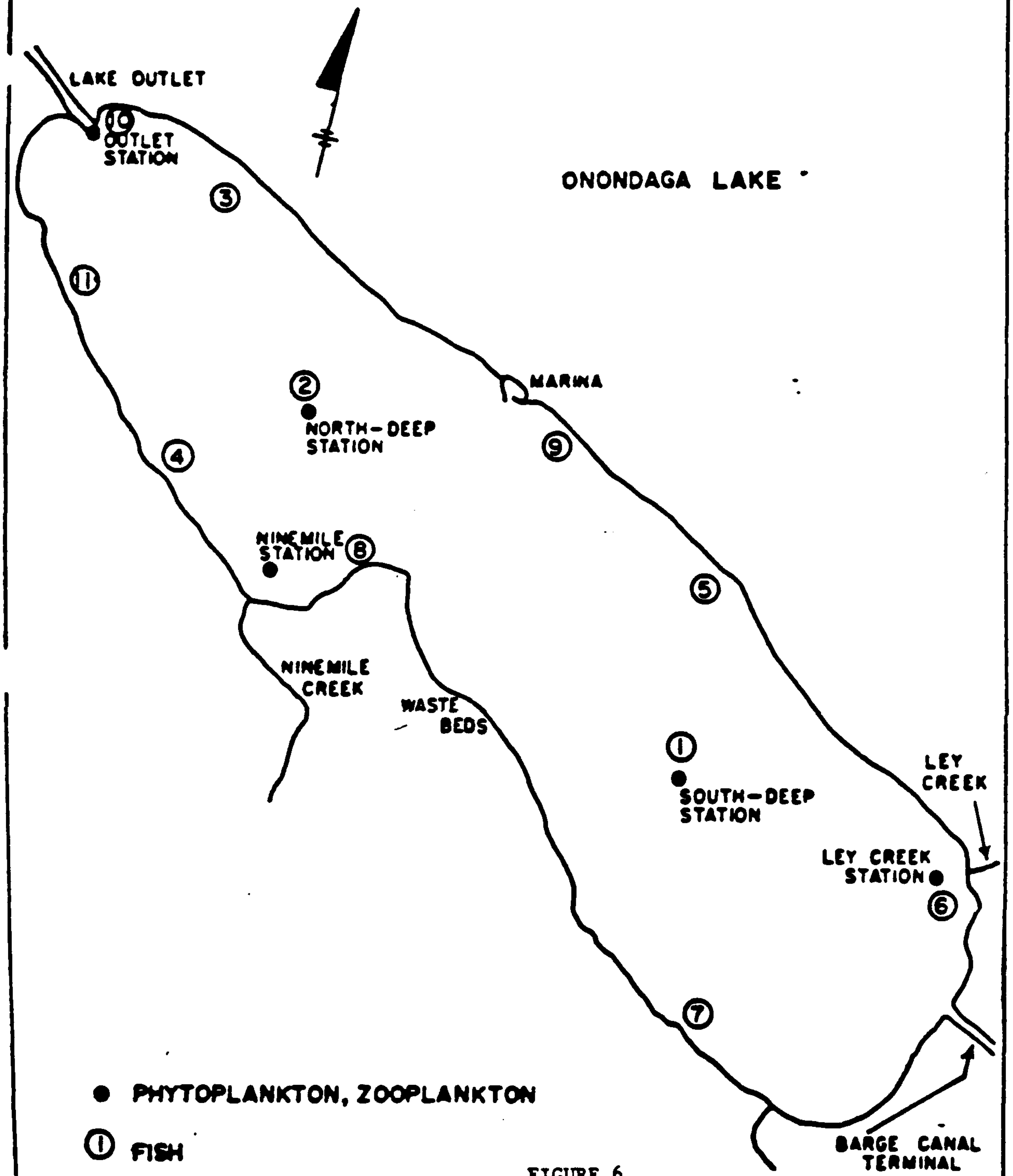


FIGURE 6

SOURCE: (Noble and Forney, 1971)
also
(Onondaga County, 1971)

BIOLOGICAL SAMPLING LOCATIONS

O'BRIEN & GERE

C-1

Creek, Onondaga Creek, Harbor Brook, and Ninemile Creek. Also, Geddes Brook, which is a tributary to Ninemile Creek was surveyed to some degree. In general, the survey found that near the mouth of almost all the streams sampled, the benthic communities were dominated by worms, midges, and sow bugs. All the tributaries surveyed contained pollution tolerant macroinvertebrate fauna. Some sampling stations on several of the streams also contained facultative benthic invertebrates, or invertebrate larvae stages indicative of improved water conditions (i.e., caddisflies, stoneflies, mayflies). Table 4 identifies the stations sampled on the tributary streams, as well as the dominant benthic invertebrate fauna collected at these stations by the Stream Biomonitoring Unit during the 1989 survey.

1.69 Fisheries - In the past, Onondaga Lake supported a coldwater fishery that included Atlantic salmon which inhabited the Lake in the early 1700's and early 1800's (Onondaga Lake Advisory Committee pamphlet). This fish species became extinct in the Lake by about late 1800. At one time in the 1800's, the Lake was probably well oxygenated, since it had a plentiful population of whitefish (Effler, et al, 1986). However, this fish species was thought to have disappeared from the Lake by 1898 (Lipe, et al, 1983), presumably because of habitat and water quality deterioration (Effler, 1987). Fish currently utilizing Onondaga Lake are comprised of warmwater species. The upper water level of the Lake down to approximately 20 feet of depth generally contains dissolved oxygen levels that allow for habitation by such warmwater fish life. Water at lower levels in the Lake may be cold, but virtually devoid of oxygen (Onondaga Lake Advisory Committee pamphlet); therefore, this deeper zone referred to as the hypolimnion does not presently support fish life. Other factors influencing the Lake's fishery are turbidity (contributing to reduced water transparency), calcium carbonate deposits (known as oncolites) along the Lake bottom, pollution (i.e., mercury and deposition of dissolved solids), and high bacterial levels. In spite of the aforementioned problems, there are a variety of fish in the Lake within the oxygenated zone above the hypolimnion. Some idea of fish diversity in the waters of Onondaga Lake is provided by available fishery survey literature and through recent communication with the New York State Department of Environmental Conservation (NYSDEC) Region 7 office.

1.70 Fishery studies done by the NYSDEC in 1969 and 1980 provide information on the diversity of warmwater fish species that utilize Onondaga Lake. Except for a well established white perch population, the fish species composition in the Lake has not changed appreciably since State surveys of this water body were made in 1927 and 1946 (Noble and Forney, 1971).

1.71 As indicated in the summer 1969 Fish Survey Report (Noble and Forney 1971), midwater trawling was conducted around mid-May to sample adult fish species, and also in early August when reproduction by adult pelagic fish was sampled. Plankton netting was done during mid-May as well as in mid-June to sample pelagic fry. Inshore fish were sampled by use of fill netting in mid-May, mid-June, and in early August. Additionally, small fish along the Onondaga Lake shoreline were captured with a bag seine. The fish survey resulted in the capture of 762 fish - which included 16 species. The variety of fish species collected included 55 adult carp (Cyprinus carpio), 4 adult emerald shiners (Notropis atherinoides), 2 adult and 5 young white suckers (Catostomus commersoni), 6 adult northern redhorse (Moxostoma macrolepidotum), 1 redhorse sucker (Moxostoma sp.), 20 adult channel catfish (Ictalurus punctatus), 3 adult and 3 young brown bullhead (Ictalurus nebulosus), 1 adult brook stickleback (Culaea inconstans), 607 adult and 10 young white perch (Roccus americanus), 5 small mouth bass (Micropterus dolomieui), 1 adult bluegill (Lepomis macrochirus), 3 adult pumpkinseeds (Lepomis gibbosus), 3 young bluegill or pumpkinseeds, 22 yellow perch (Perca flavescens), 5 adult walleye (Stizostedion vetreum), and 6 adult freshwater drum (Aplodinotus grunniens). In general, the 1969 survey found that carp appeared to be common and that there was some probable sunfish spawning in the Lake. Also, since no young yellow perch were collected, the report mentions that reproduction by this fish species in the Lake may be poor. Few adult fish were captured in the southernmost portion of the Lake durind the survey and, there was a lack of young fish along the Lake's northwest shoreline. Limited reproductive success of fish in the littoral zone of the Lake may be influenced by substrate of poor quality, scarecity, and/or lack of adequate fish spawning habitat, as well as poor water quality inflow.

1.72 In July 1980, the NYSDEC conducted another fisheries survey in Onondaga Lake, whereby extensive net sampling was utilized, which included use of trap and gill nets as well as a beach seine (Chiotti, 1981). The survey captured about 4,816 fish - representing 22 species. In addition to 3,015 white perch, 167 pumpkinseed sunfish, 166 yellow perch, 121 smallmouth bass, 114 carp, 109 brown bullhead, 65 channel catfish, 58 which suckers, 45 redhorse suckers, 36 walleye, 21 freshwater drum (sheepshead), and 17 bluegills, ten other fish species were also captured. About 683 alewife (Alosa pseudoharengus), 96 gizzard shad (Dorosoma cepedianum), 56 black crappie Pomoxis nigromaculatus), 22 white crappie (Pomoxis annularis), 13 northern pike (Esox lucius), 5 golden shiners (Notemigonus crysoleucas), 4 bowfin (Amia calva), 1 largemouth bass (Micropterus salmoides), 1 gar (Lipososteus sp.), and 1 lake trout (Salvelinus namaycusch) comprised the remainder of the 22 species list. As indicated in the 1981 Onondaga Lake Survey Report by Chiotti, coldwater fish normally do not inhabit the

Lake due to limited oxygen levels in water near the top of the Lake's thermocline. The report further indicated that in the 1980 NYSDEC Lake survey, there were moderate densities of walleyes and smallmouth bass found in the net sampling, as well as a relatively abundant population of bullhead, channel catfish, yellow perch, pumpkinseed sunfish, brown bullhead, and black crappie. With regard to fish spawning and immigration the survey report mentioned that sporadic reproduction and adult recruitment occurs in the Lake for a number of species and that walleye and northern pike likely access the Lake via the Lake's outlet from the Seneca River and possibly through other connecting channel ways.

1.73 In July 1983, gill and trap net sets were placed in Onondaga Lake by NYSDEC Region 7 fisheries personnel. Gill net settings for 6 nights and trap net settings for 12 nights resulted in a catch of 50 smallmouth bass ranging in length from 241 to 410 millimeters (about 9-1/2 to 16-1/8 inches). Most of the net settings appeared to be along the east side of the Lake (Personal Communication with NYSDEC Region 7, 30 June 1990).

1.74 Fishery survey information for tributaries to Onondaga Lake is limited. Some data on utilization of Ninemile Creek by fish was obtained through coordination with the Region 7 NYSDEC office. An electroshocking fish survey conducted by the NYSDEC in July 1977 sampled 8 stations in Ninemile Creek, starting from a point about 2,000 feet above its junction with Geddes Brook in the town of Geddes upstream to a point about 2,000 feet below Tributary 6 (which is a NYSDEC identified tributary located in the general vicinity of an aquaduct downstream of the village of Marcellus Falls, in the town of Camillus. Seventeen species of fish were represented in the collection. Fish caught in the July 1977 survey included a number of brown trout (Salmo trutta) - some of which were fingerlings and yearlings - brook trout (Salvalinus fontinalis), longnose dace (Rhinicthys cataractae), white suckers, tesselated darters (Etheostoma olmstedi), pumpkinseed, carp, creek chub (Semotilus atromaculatus), Johnny darter (Etheostoma nigrum), smallmouth bass, rockbass (Ambloplites rupestris), brown bullhead, yellow perch, common shiner (Notropis cornutus), blacknose dace (Rhinicthys atratulus), central mudminnow (Unbra limi), northern hogsucker, and (Hypentelium nigricans). In general, Ninemile Creek contains both stocked and wild trout and is still considered to be an excellent stream for this coldwater fish species - particularly between Marcellus and Camillus where colder water comes into the Creek (Cooper, et al, 1974). With regard to other tributaries into or out of Onondaga Lake, the Lake Outlet and Barge Canal support a warmwater fishery, whereas Harbor Brook occasionally receives stockings of brown trout and contains some resident trout as well. A portion of Onondaga Creek has stocked brown trout and there is also some natural reproduction of this species as well. Sawmill Creek, Bloody Brook, and Ley Creek currently

do not receive significant use by Onondaga Lake fishes, although gizzard shad and carp are known to utilize Ley Creek (Personal Communication with NYSDEC Region 7 on 30 May 1990 and on 11 September 1990).

1.75 Although there are a diversity of fish associated with Onondaga Lake, in 1972, the NYSDEC has prohibited human consumption of fish from the Lake, due to high concentrations of mercury in the flesh of these aquatic organisms (Effler, 1987). Although, in 1986, the Lake was reopened to public fishing by NYSDEC, there still is a posted health advisory warning along the Lake's shoreline, advising the public against eating the fish flesh.

1.76 Vegetation - Cursory observations at some locations along the peripheral riparian shoreline of Onondaga Lake and its major tributaries during a May 8-9, 1989 field trip by several members of the Corps of Engineers, Buffalo District, provided a broad overview of existing woody and herbaceous vegetation in the general vicinity of the study area. Brief observations of aquatic macrophytes as well as trees, shrubs, grasses, and forbs along the riparian Lake and tributary shoreline areas were noted as indicated at the following locations; also, a rough visual subjective estimate of plant abundance was noted and is indicated as "S" for some, "C" for common, or "A" for abundant:

-- Onondaga Creek in the vicinity of Franklin Square, Syracuse, New York: Eastern Cottonwood (Populus deltoides) - S, Blackwillow (Salix nigra) - C, Sugar Maple (Acer saccharum) - S, Elm (Ulmus sp.) - S, Boxelder (Acer negundo) - C, Choke-Cherry (Prunus virginiana) - S, Staghorn Sumac (Rhus typhina) - S, Japanese Knotweed (Polygonum cuspidatum) - S, Wild Grape (Vitis sp.) - C, Bittersweet Nightshade (Solanum dulcamara) - S, Virginia Creeper (Parthenocissus quinquefolia) - S, Jewelweed (Impatiens sp.), Garlic Mustard (Alliaria officinalis) - C, Jewelweed (Impatiens), and Grass (sp.) - C.

-- Onondaga Creek Outlet Area: Black Willow - S, Eastern Cottonwood - C, Staghorn Sumac - S, Red-Osier Dogwood (Cornus stolonifera) - S, Honeysuckle (Lonicera sp.) - S, Wild Grape - C, Garlic Mustard - C, Smartweed (Polygonum sp.) - S, Goldenrod (Solidago sp.) - C, and Giant Reed (Phragmites sp.) - S.

-- Ley Creek vicinity of bridge at Route 81 overpass: Boxelder - C, Eastern Cottonwood - S, Black Willow - S, Staghorn Sumac - S, Giant Reed - C, and Japanese Knotweed - C.

-- Ley Creek vicinity of 7th North Street bridge: Eastern Cottonwood - C, Black Willow - S, Boxelder - C, Tree-of-Heaven (Ailanthus altissima) - S, Willow (Salix sp.) - C, Garlic Mustard - S, Giant Reed - C, Reed Canarygrass (Phalaris arundinacea) - C, and Cattail (Typha sp.).

-- Ley Creek vicinity of Factory Avenue and Twin Oaks Drive: Boxelder - C, Quaking Aspen (Populus tremuloides) - S, Giant Reed - A, and Horsetail (Equisetum sp.) - C.

-- Riparian Shoreline in vicinity of Onondaga Lake Park: Green Algae in shallow water along shore (Chladophora sp.) - C, Silverweed (Potentilla anserina) - C, Eastern Cottonwood - C, Black Willow - C, Willow (Salix sp.) - C, Boxelder - C, Buckthorn (Rhamnus sp.) - C, Ash (Fraxinus sp.) - S, Red-Osier Dogwood - C, Staghorn Sumac - S, Silverweed - C, Horsetail - S, Common Dandelion (Taraxacum officinale), and Gill-Over-the-Ground (Glenchoma hederacea).

-- Mouth of Bloody Brook vicinity: Boxelder - S, Eastern Cottonwood - S, Elm - S, Blackwalnut (Juglans nigra) - S, Scotch Pine (Pinus sylvestris) - S, Red-Osier Dogwood - S, Gray Dogwood (Cornus racemosa) - S, Buckthorn - S, Wild Grape - C, Raspberry (Rubus sp.) - S, Virginia Creeper (Parthenocissus quinquefolia) - C, Tatarian Honeysuckle (Lonicera tatarica) - S, American Cranberrybush (Viburnum trilobum) - S, Jewelweed - C, Nettle (Urtica sp.), Burdock (Arctium minus) - S, Privet (Ligustrum sp.) - S, and Green Algae - C.

-- North end of Onondaga Lake (Vicinity of Mouth of Sawmill Creek and along riparian shoreline area of Onondaga County Park): Ash - S, Black Willow - C, Sugar Maple - C, Eastern Cottonwood - C, White Spruce (Picea alba) - S, Willow (Salix sp.) - C, Goldenrod - C, Nettle - S, Red-Osier Dogwood - S, Jewelweed - C, Common Dandelion - C, Burdock - S, Wild Grape - S, Poison Ivy (Rhus typhina) - S, Iris (Iris sp.) - C, Smartweed - S, Arrowhead (Sagittaria sp.), and Green Algae (Chladophora sp.).

-- North end of Onondaga Lake (Palustrine forested broad-leaved deciduous seasonally saturated, scrub/shrub wetlands): Red Maple (Acer rubrum) - C, Ash - C, Eastern Cottonwood - C, Willow (Salix sp.), Boxelder - S, Elm - S, Buckthorn - C, Gooseberry (Ribes sp.), Choke-Cherry - S, Poison Ivy - C, Wild Grape - C, Iris - C, Jewelweed - C, Smartweed - C, Cattail - C, Sensitive Fern (Onoclea sensibilis) - C, Arrowwood (Viburnum sp.) - S, Honeysuckle - C, Giant Reed - C, and Buttercup (Ranunculus sp.) - S.

-- Ninemile Creek in vicinity of bridge on State Fair Boulevard: Both banks well vegetated primarily with Giant Reed - A, and Black Willow trees - C.

1.77 Wildlife - "Wildlife is an important resource in Onondaga County" (Soil Conservation Service, 1977). Although the general locale in the vicinity of Onondaga Lake and its major tributaries is predominantly developed (i.e., industrial, commercial, and residential), a variety of wildlife inhabits the vegetated areas peripheral to the Lake and along its tributary

streams. Game and non-game species of birds, mammals, amphibians, and reptiles utilize the openland, woodland, idle land, urban parkland, and remaining wetland habitats in the vicinity of the Lake and its waterways. Among the wildlife species associated with openland habitat containing scattered areas of mixed grasses, shrubs, young trees, and vines are the eastern cottontail rabbit, mourning dove, field sparrow, woodchuck, red fox, striped skunk, opossum, voles, moles, and mice. Examples of woodland wildlife that may be found are whitetail deer, ruffed grouse, thrush, vireos, warblers, gray and red squirrels, and raccoon. Among the wildlife that likely utilize nearby wetlands peripheral to the Lake are rails, herons, bitterns, mink, and muskrats, as well as waterfowl such as dabbling ducks. The open area of Onondaga Lake is utilized by waterfowl (i.e., ducks, Canada geese) as resting and feeding habitat - particularly during spring and fall migratory periods.

1.78 Information on wildlife species - including reptiles and amphibians - that are specific to the general vicinity of Onondaga Lake and its tributaries is sparse. However, with regard to birds, amphibians, and reptiles, a review of map information provided in "The Atlas of Breeding Birds in New York State" (Anderle and Carroll, Ed., 1988), and in "A Field Guide to Reptiles and Amphibians" (Conant, 1958), provide some insight on the variety of wildlife that have a range in the State of New York which includes Onondaga County. Approximately 150 species of birds were sighted by observers as being either possible, probable, or confirmed breeders in Onondaga County during the bird breeding survey that was conducted from 1980 to 1985. A diversity of waterfowl, grebes, herons, hawks, owls, rails, shorebirds, woodpeckers, flycatchers, swallows, wrens, thrush, vireos, warblers, sparrows, and other birds were recorded. With regard to amphibians and reptiles, about 37 species have ranges that include Onondaga County; these species consist of a variety of turtles, salamanders, snakes, and frogs.

1.79 During a recent cursory field trip to Onondaga Lake and its tributaries on May 8-9 by a Corps Ecologist, the following wildlife species were observed: Blackburnian Warbler (Dendroica fusea), Cormorant (Phalacrocorax sp.), Mourning Dove (Zenaidura macroura), Common Grackle (Quiscalus quiscula), Purple Martin (Progne subis), Robin (Turdus migratorius), Song Sparrow (Melospiza melodia), Ringbill Gull (Larus delawarensis), Redwing Blackbird (Agelaius phoeniceus), Barnswallow (Hirundo rustica), Common Crow (Corvus branchynchos), Great Blue Heron (Ardea herodias), Rock Dove (Columbia livia), Whitetail Deer (Odocoileus virginianus), Cottontail Rabbit (Sylvilagus floridanus), Raccoon (Procyon lotor) - dead carcass along the lakeshore, and Woodchuck (Marmota monax).

1.80 Threatened and Endangered Species - As indicated in a recent Planning Aid Letter to the Buffalo District dated December 28, 1990 prepared by the U. S. Fish and Wildlife Service, except for occasional transient individuals, no Federally listed or proposed endangered or threatened species are know to exist in the potential project area of Onondaga Lake. Also, the New York State Department of Environmental Conservation Wildlife Resources Center indicated in a letter to the Corps dated 5 October 1990, that their present file information did not identify any knwon occurrences of rare plants or animals or significant habitats on Onondaga Lake or within one mile of its shoreline.

1.81 Wetlands - With regard to freshwater wetlands, a review of the Syracuse West U.S. Geological Survey Quadrangle map indicated that there are a number of wetlands regulated by the New York State Department of Environmental Conservation (NYSDEC) near the Onondaga Lake shoreline. These wetlands are identified by map symbols at the following locations on the quadrangle map: SYW1 along the northeast shoreline in the vicinity of Lake park; SYW6 consisting of a series of small parceled wetlands along the northwest shoreline near Maple Bay; SYW10 about midway along the west shoreline; SYW19 at the southwest corner of the Lake; and SYW12 at the northeast corner of the Lake - both within the city of Syracuse boundary of Onondaga Lake. The U.S. Department of Interior also identifies most of the shoreline area of Onondaga Lake as being a lacustrine littoral permanent open water zone, with some small areas of wetland at the southwest and northeast ends of the Lake in palustrine emergent persistent vegetation such as tall reedgrass and cattails.

SECTION 2 - NEED FOR STUDY AND OBJECTIVES

INTRODUCTION

2.01 This section briefly summarizes why the Corps became involved in the study and what public concerns and subsequent planning objectives were identified as the basis for measure consideration. Reference associated sections of the Main Report and Appendices for more details on need for study and objectives.

STUDY AUTHORITY

2.02 This study is being conducted as authorized by: Resolution, Committee of the Environment and Public Works of the U.S. Senate, June 1989.

PROBLEMS AND NEEDS

2.03 Onondaga Lake and its tributaries have been greatly impacted by both domestic and industrial wastes that accompanied the development of the Syracuse area since the late 1800s. Reference Community and Regional Growth in SECTION 1 - ENVIRONMENTAL SETTING. Water and sediment quality pollution problems include those pertaining to: ammonia, phosphorous, sodium, calcium, chloride, metals (zinc, lead, copper, chromium, cadmium, mercury, iron), chlorobenzene, fecal coliform, high turbidity, altered nearshore sediments (i.e., calcium carbonate, phosphorous, mercury, etc.), and resultant associated system processes.

2.04 Reference Figure 7 depicts Onondaga Lake and the location of its major tributaries. Reference Table 5 provides a selective listing of the problems of the lake. Reference Table 6 provides a listing of the lakes major tributaries, inflows, and some associated past and/or present pollutants. Reference Figure 8 depicts occurrence of oncolites and $CaCo_3$ delta. Figure 9 depicts concentrations of mercury in lake sediments.

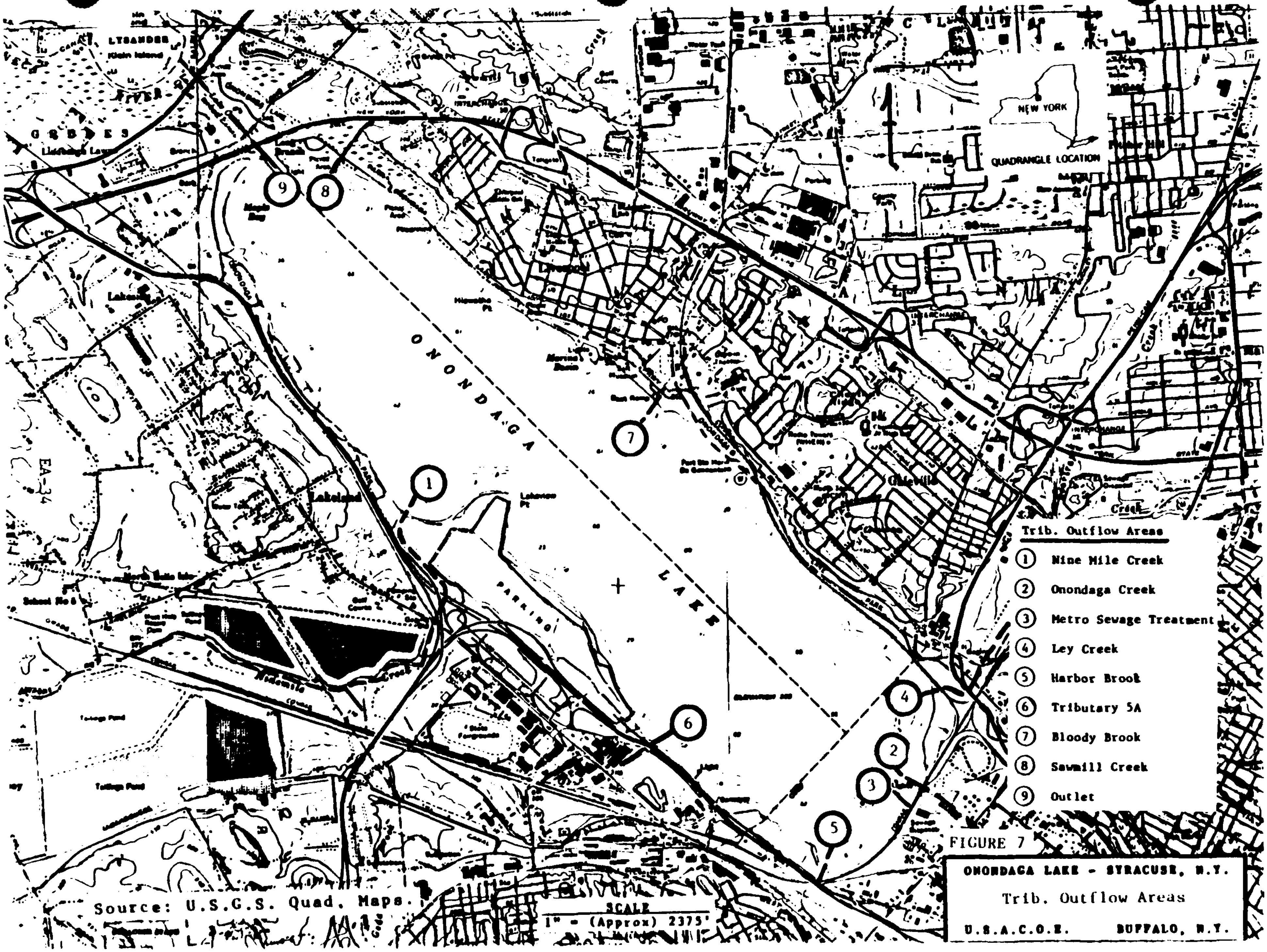


FIGURE 7

ONONDAGA LAKE - SYRACUSE, N.Y.

Trib. Outflow Areas

U.S.A.C.O.E. BUFFALO, N.Y.

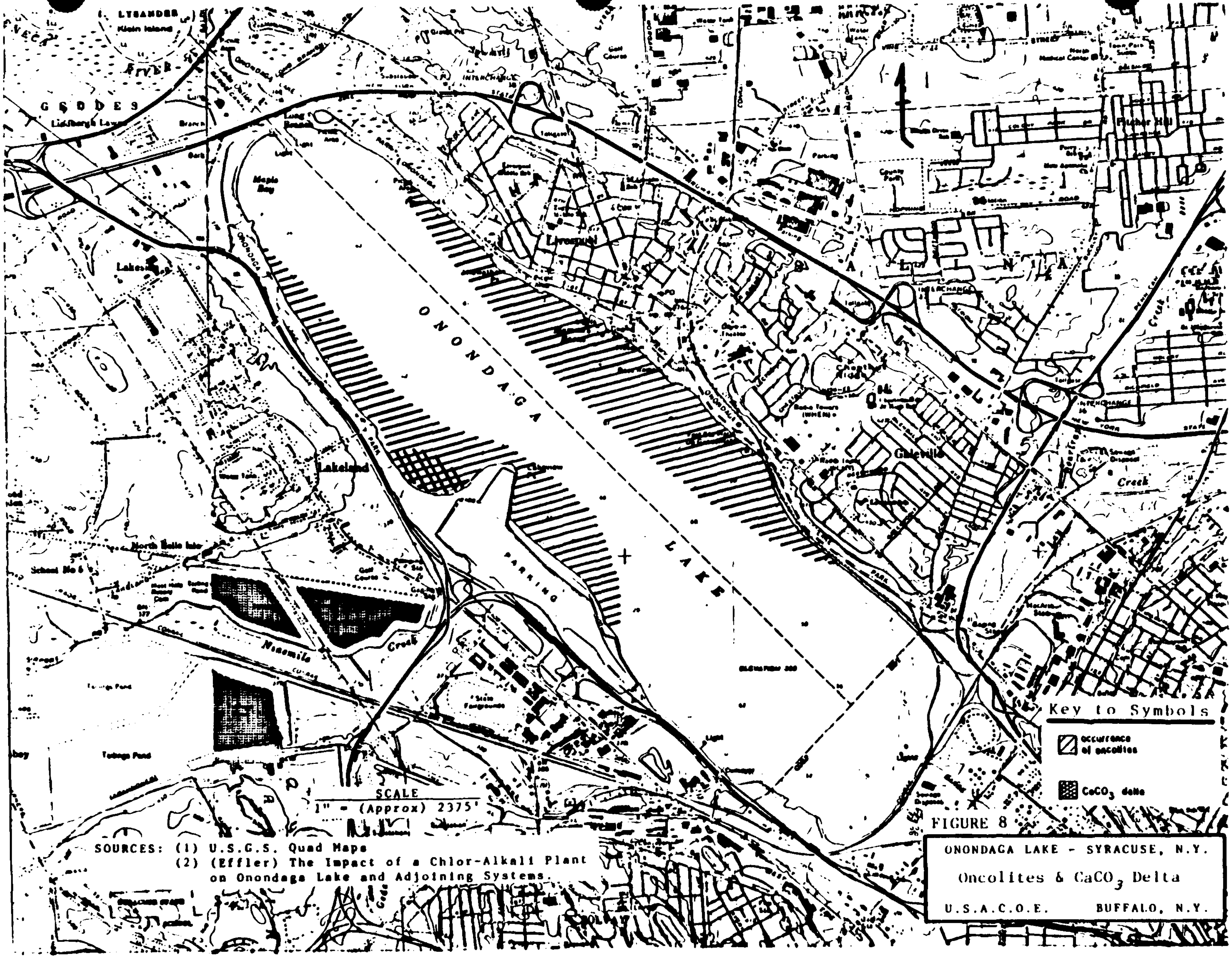
Table 5 - Water Quality Related Problems of Onondaga Lake

1. high concentrations of ammonia
2. low transparency
   - high loading of phosphorus
   - high concentrations of phytoplankton
3. low concentrations of dissolved oxygen
4. high concentrations of fecal coliforms
5. mercury contamination
   - fish flesh
   - sediments
6. sediment releases
   - nutrients
   - toxics
7. high sedimentation rates
8. chlorobenzene contamination
9. ionic enrichment
10. altered near-shore sediments
11. altered food chain interactions
12. impact of lake releases on river quality

(Effler, 1989)

Table 6 - Onondaga Lake Tributaries, Inflows, Pollutants

Tributary (Inflow)	Pollutants
1. Ninemile (38 %)	(2) Treated Wastewater (Camillus, Marcellus) Wastebed (Overflow & Infiltration) Inorganic Salts (Sodium, Calcium, Chloride) Heavy Metals (Zinc, Lead, Copper, Chromium, Cadmium, and Mercury)
2. Onondaga (34%)	(53) Combined Sewer Overflows Fecal Coliform Bacteria Salts Heavy Metals (Lead, Copper, Chromium) High Sedimentation
3. Metro Sewage Treatment Plt. (17%)	Treated Wastewater (Syracuse)
4. Ley (8%)	(2) Combined Sewer Overflows (2) Sanitary Sewer Overflows (Brooklawn and Ley Creek) BOD Bacteria Sanitary Landfill
5. Harbor Brook (3%)	20 Combined Sewer Overflows (Hillcrest Brookside) Inorganic Carbon Particulate Organic Carbon Metals (Copper, Lead)
6. Trib. 5A (Minor)	Treated Wastewater (Crucible Steel) Reduced loadings now - Industrial Wastewater Reuse and Treatment Historically Metals (Iron, Chromium, Copper)
7. Bloody Brook (Minor)	Treated Coolant & Wastewater (General Electric)
8. Sawmill (Minor)	



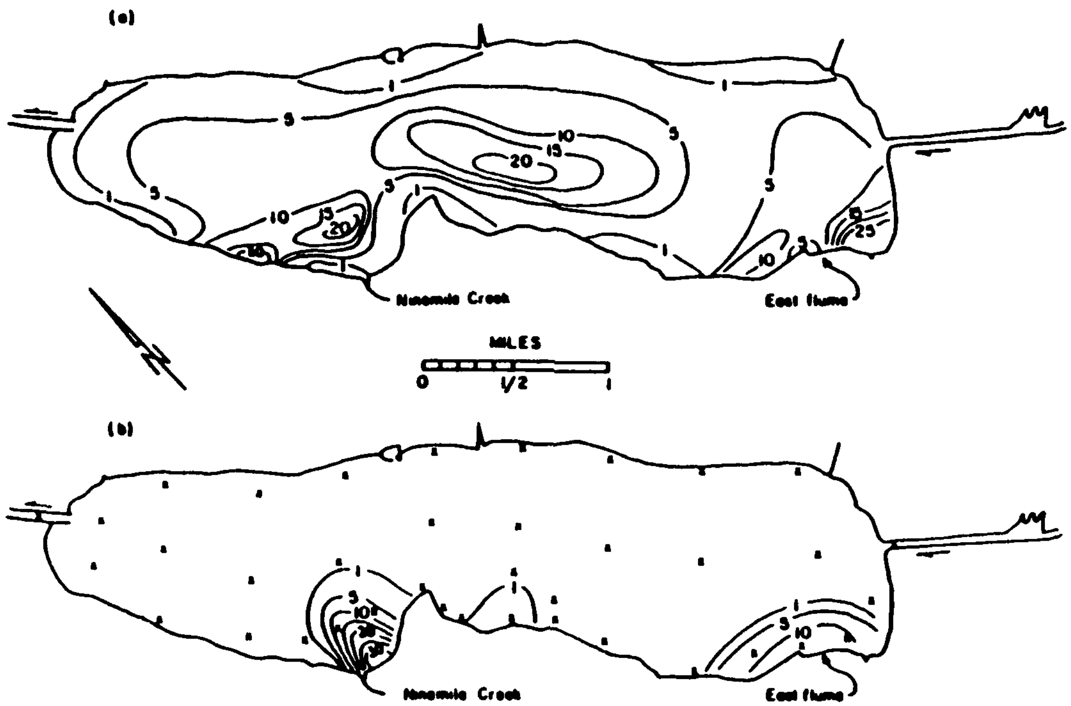
SOURCES: (1) U.S.G.S. Quad Maps
(2) (Effler) The Impact of a Chlor-Alkali Plant on Onondaga Lake and Adjoining Systems.

FIGURE 8

ONONDAGA LAKE - SYRACUSE, N.Y.

Oncolites & $CaCO_3$ Delta

U.S.A.C.O.E. BUFFALO, N.Y.



Contours of total Hg (mg/kg) in the sediments of Onondaga Lake in 1970: (a) depth of 7.5 cm and (b) depth of 30 cm, with core sample locations (USEPA, 1973).

SOURCES: (1) (Effler) The Impact of a Chlor-Alkali Plant on Onondaga Lake and Adjoining Systems.

FIGURE 9

ONONDAGA LAKE - SYRACUSE, N.Y.

Mercury Contamination

U.S.A.C.O.E. BUFFALO, N.Y.

2.05 Swimming is prohibited because of high concentrations of fecal bacteria and low transparency. Other water and sediment quality pollution problems likely exist in this regard for which there may not be any health and safety standards.

2.06 The fishery of the lake is negatively impacted by the prevalence of high concentrations of ammonia, low concentration of oxygen, the degraded conditions of the sediments (and habitat), and concentration of fish flesh with mercury.

2.07 Pollution problems in Onondaga Lake also pollute the lake outlet and the Seneca River.

2.08 The problems and needs associated with Onondaga Lake are significant and complex. Much has been accomplished to understand the problems and relationships, but much more pertaining to specifics needs to be done. The Onondaga County Department of Drainage and Sanitation has been monitoring the water quality in Onondaga Lake. Reference Table 7 depicts Onondaga Lake yearly volume-averaged concentrations in 1987 in the Epilimnion (Upper) and Hypolimnion (Lower) level of the Lake and averaged in 1989 for various water quality parameters as compared to water quality standards as noted. Much has been accomplished in reducing the discharge of pollutants (i.e., improvements to sewage treatment plants, closure of polluting facilities or improvement to standards of discharge facilities, etc.) with associated improvements to water quality; but more needs to be done. Even if pollution discharges are controlled and water quality improves, residual pollutants in the sediments may be a problem via recycling of sediment pollution precipitates back into the water.

2.09 Needed clean-up measures pertain therefore to control at pollution sources, clean-up of water quality, and clean-up of sediment quality.

2.10 The Buffalo District is investigating public concerns and potential measures for addressing these concerns. Initially, a wide spectrum of both non-structural and structural measures are considered. They are examined alone and in combination for their: engineering and economic feasibility, environmental and social acceptability, and/or overall ability to meet the identified planning objectives.

PLANNING OBJECTIVES

2.11 The Federal objective of water and related land resources project planning is to contribute to National Economic Development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable Executive Orders, and other Federal planning requirements.

Table 7A -

ONONDAGA LAKE
YEARLY VOLUME-AVERAGED CONCENTRATIONS
1987

PARAMETER	Upper Level EPILIMNION CONCENTRATION	Lower Level HYPOLIMNION CONCENTRATION
Na	251.	248.
Ca	191.	208.
Zn	.010	.013
Pb	.020	.021
Cr	.008	.008
Cu	.011	.013
Cd	.005	.005
Hg	.2	.2
Total Coli	633.	621.
Fecal Coli	67.	38.
TOC	6.4	6.2
TIC	33.7	46.8
Fil. TOC	5.8	5.7
Ortho P	.095	.403
TIP	.146	.454
BOD 5	5.5	9.4
DO	8.2	3.3
Temp.	14.8	9.1
Spec.Con.	2564.	2659.
Cl	623.	629.
NH3-N	2.2	4.4
Org-N	1.4	1.8
TKN	3.6	6.1
NO3-N	.93	.35
NO2-N	.28	.12
pH	7.5	7.3
SO4	173.	164.
Secchi depth	1.3	N/A
Total Alk.	153.	200.
CO2	7.8	18.1
Part. TKN	.5	.7
Fil. TKN	3.0	4.5
Susp.Solid	7.4	5.6
Vol.S.Solid	6.2	4.8
Chlyp.-A	.025	.007
SiO2	.96	2.1
Phaeopig.	.010	.005
Total Solid	1661.	1706.
Vol.T.Solid	304.	333.
Fecal Strep	67.	81.
Sol.TIP	.097	.317

UNITS mg/l except for the following:

TEMP	- degrees Celsius	FECAL STREP	- cells/100 ml.
pH	- standard units	SPECIFIC COND.	- micromhos/cm
TOTAL COLI	- cells/100 ml.	SECCHI DEPTH	- meters
FECAL COLI	- cells/100 ml.	MERCURY	- ug/l

Source:OCOLMPAR

Table 7B - **Comparison of Present Conditions With State Water Quality Standards**

PARAMETER	Suitable For: 1989 Existing Peak Average (1)	Swimming Goal	Acceptable Cold Water Fishery Goal	Drinking Water Supply Source Goal
Secci Depth	3.3' / 5.2'	4'(4)	-	-(+)
Total Coliform	251	<2400/100ml(4)	-	-(+)
Fecal Coliform	(#)	200/100mg(4)	-	-(+)
(hypolimnion) Ammonia	6.0 / 3.6	-	2.06mg/l (1,8) / 0.27mg/l (5)	2.06mg/l (2,8)
(hypolimnion) DO	0.0 / 7.5	-	6mg/l (1)	5mg/l (2)
Mercury	.2ppb	-	0.002mg/l(1,*)	0.002mg/l (1,', *) / 0.005mg/l(2)
Nitrite	.72 / .182	-	0.02 mg/l(2)	10 mg/l(1,2,7)
Nitrate	5.0 / 1.49	-	-	10 mg/l(1,2,3,7)
Sodium	255 / 200	-	-	<20mg/l(1,2,6)
(hypolimnion) Calcium	190 / 159	-	-	-
(hypolimnion) Zinc	.065 / .024	-	0.03 mg/l(1)	<0.3 mg/l(1,2) / 5 mg/l (3)
(hypolimnion) Cadmium	.013 / .003	-	-	<.01mg/l (1,2,3)
Copper	.07 / .020	-	-	< 2mg/l(1,2) / 1mg/l (3)
Chloride	510 / 458	-	250 mg/l (1)	250 mg/l(1,2,3)

1 Water Quality Standards and Guidance Values, DEC 9/25/90
2 New York State DEC Codes, Rules and Regulations Section 170.4
3 Chpt I State Sanitary Code, subpart 5-1 Public Water Supplies 1/19/90
4 Chpt I State Sanitary Code, subpart 6-2 Bathing Beaches 3/30/88
5 Defined by UFI
6 From 3 No designated limits <20 mg/l for severely restricted Na diets <270 mg/l for moderately restricted Na diets
7 Nitrate & Nitrite in combination
8 Total NH3-N at pH=7.25 & Temp=20°C, unionized value= 0.0144mg/l
* Guidance value is 0.0002mg/l
\+ Not considered, easily treatable
\# Not specified, too variable

Source:CENCBPE-HO

2.12 Planning objectives which were derived from resource management needs and utilized in plan formulation for the project vicinity include:

a. To facilitate, where possible, prevention of pollution and clean-up of Onondaga Lake water and sediment quality in order to facilitate future community economic and social well-being and environmental quality.

b. To reduce health and safety hazards associated with pollution in Onondaga Lake during and via clean-up measures.

c. To consider and to minimize any adverse impacts to other water resource interests during and via clean-up measures.

d. To protect and enhance, where possible, the fish and wildlife resources (habitat) in the project vicinity, in order to enhance natural environmental quality.

e. To preserve, as necessary, cultural resources in the project vicinity in order to protect cultural heritage.

f. To encourage wise water and land use practices around the lake, consistent with wise development, health and safety, and environmental principles to protect future community economic and social well-being and environmental quality.

SECTION 3 - MEASURE CONSIDERATIONS

INTRODUCTION

3.01 Reference this section of the Main Report and Water Quality Appendix. This section briefly discusses initial measures under consideration and generated environmental enhancement plans.

GENERAL

3.02 The measures that are under evaluation for the Onondaga Lake Report are divided into General and Other (by others). The General measures include dredging and disposal, solidification, capping, in-lake treatment, and evaluation of non-point sources. The Other measures involve the reduction of pollutant loadings presently discharged to Onondaga Lake and its tributaries from the Metropolitan Syracuse sewage treatment plant (METRO STP) and Combined Sewer Overflows located within the METRO STP service area. It has been determined that the no action alternative is not acceptable due to the severity of the problem.

3.03 At this stage of the analysis, the feasibility of the measures has not been determined. A brief description of considered measures is provided below.

GENERAL MEASURES

a. Dredging

3.04 One of the measures considered for the remediation of Onondaga Lake is the removal and confinement of contaminated sediments. It has been estimated that from 2,000,000 to 6,500,000 cubic yards of sediment, covering an area of 1,880 to 2,610 acres, would have to be dredged from Onondaga Lake. The dredging would range from shallow near shore areas to the deepest portions of the lake, dredging approximately 0.5 to several feet. It is anticipated that dredging will be performed in a manner and with equipment that will limit the resuspension of sediments. This report was prepared based on the anticipation that a hydraulic dredge would be used. The cutterhead dredge has been found to be an effective hydraulic pipeline dredge in limiting sediment resuspension while removing fine-grained unconsolidated material. Reference Figures 10 through 12.

b. Confined Disposal Facility

3.05 The dredged material would be placed in a confined disposal facility (CDF) constructed along the shoreline on Onondaga Lake. For this Report, it was anticipated that the CDF would be built adjacent to Lakeview

Point and the Solvey Process Waste Beds. Depending on the quantity of material and the configuration used, the CDF would cover an area ranging from 55 to 92 acres in size. The facilities range from 34 to 63 feet in height. These facilities would be constructed in maximum water depths ranging from 6 to 22 feet. Reference Figures 13 through 15.

c. Solidification

3.06 Once in the CDF, the contaminated sediments may or may not be further immobilized. The solidification/stabilization treatment immobilizes contaminants by binding them into a concrete like, leach-resistant mass. Binder material may be in the form of cements or pozzolans; proprietary additives may also be added. Mixing of the settling agent with dredged material can be accomplished by placing the sediment into a mixing plant or by mixing in-situ with conventional construction equipment. The potential for chemicals to interfere with the solidification process has been established and further evaluation will be required for full-scale implementation of solidification processes.

d. Capping

3.07 A disposal measure considered for the contaminated sediments was subaquatic burial. The option involves the capping of contaminated sediments with cleaner borrow material. From 1,880 to 2,610 acres of lake sediments would require capping in order to isolate contaminated sediments with various concentrations. For contaminated sediments in less than 15 feet of water, a three layer cap consisting of 3 feet of sand covered by 2 feet of gravel and 2 feet of armor stone (6 to 18 inch in size) would be required. In water depths ranging from 15 to 25 feet, contaminated sediments would be covered with a two layer cap consisting of 3 feet of sand covered by 2 feet of gravel. In water depths exceeding 25 feet, the sediments would be covered only with the sand capping material. It is anticipated that this sand cap would be between 0.5 and 3.0 feet thick. For this report, it was assumed that 10 percent of the areas to be capped would be covered with the three layer cap while 15 percent of the area to be capped would be covered with the two layer system. The remaining 75 percent of the area would be covered only with 0.5 to 3.0 feet of the sand capping material. It is anticipated that sand borrow will be available within 10 miles while the gravel and armor stone will be obtained from quarries in the area.

e. In-lake Treatment

3.08 An appreciable improvement in water quality can sometimes be achieved by treating the lake water directly in place. The two most common treatments are mixing and nutrient

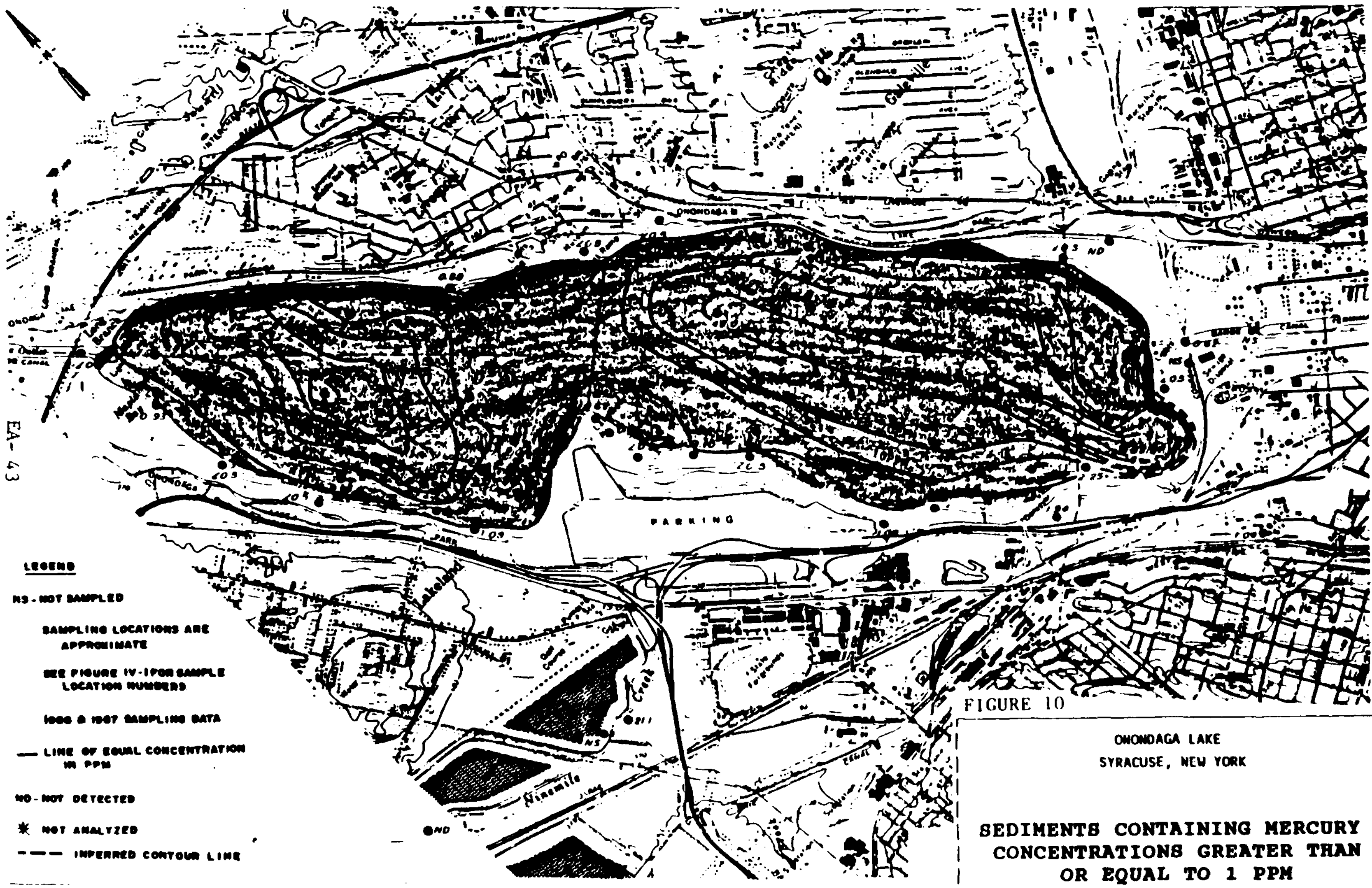


FIGURE 10

ONONDAGA LAKE
SYRACUSE, NEW YORK

SEDIMENTS CONTAINING MERCURY CONCENTRATIONS GREATER THAN OR EQUAL TO 1 PPM

U.S. ARMY ENGINEER DISTRICT, BUFFALO

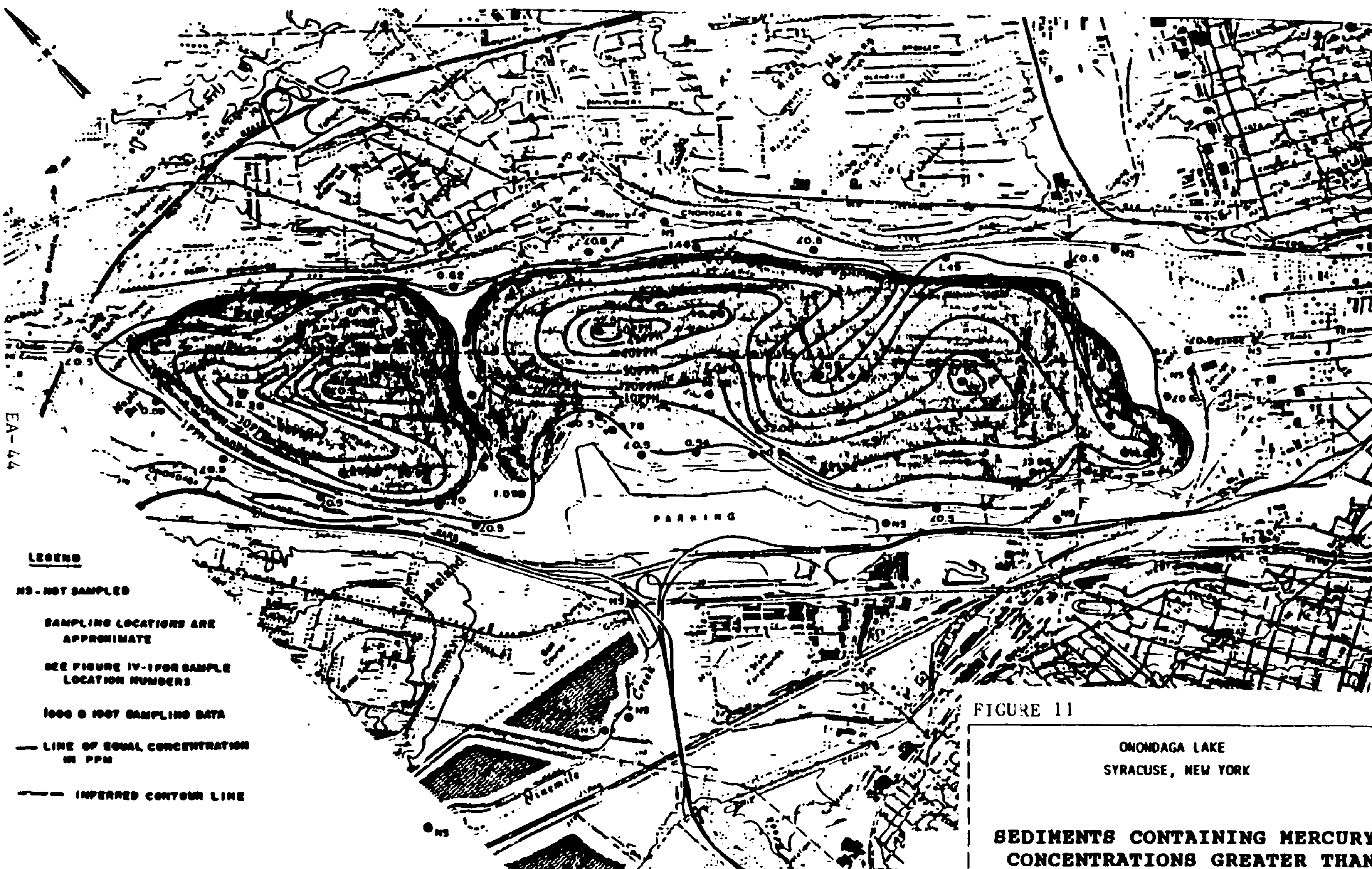
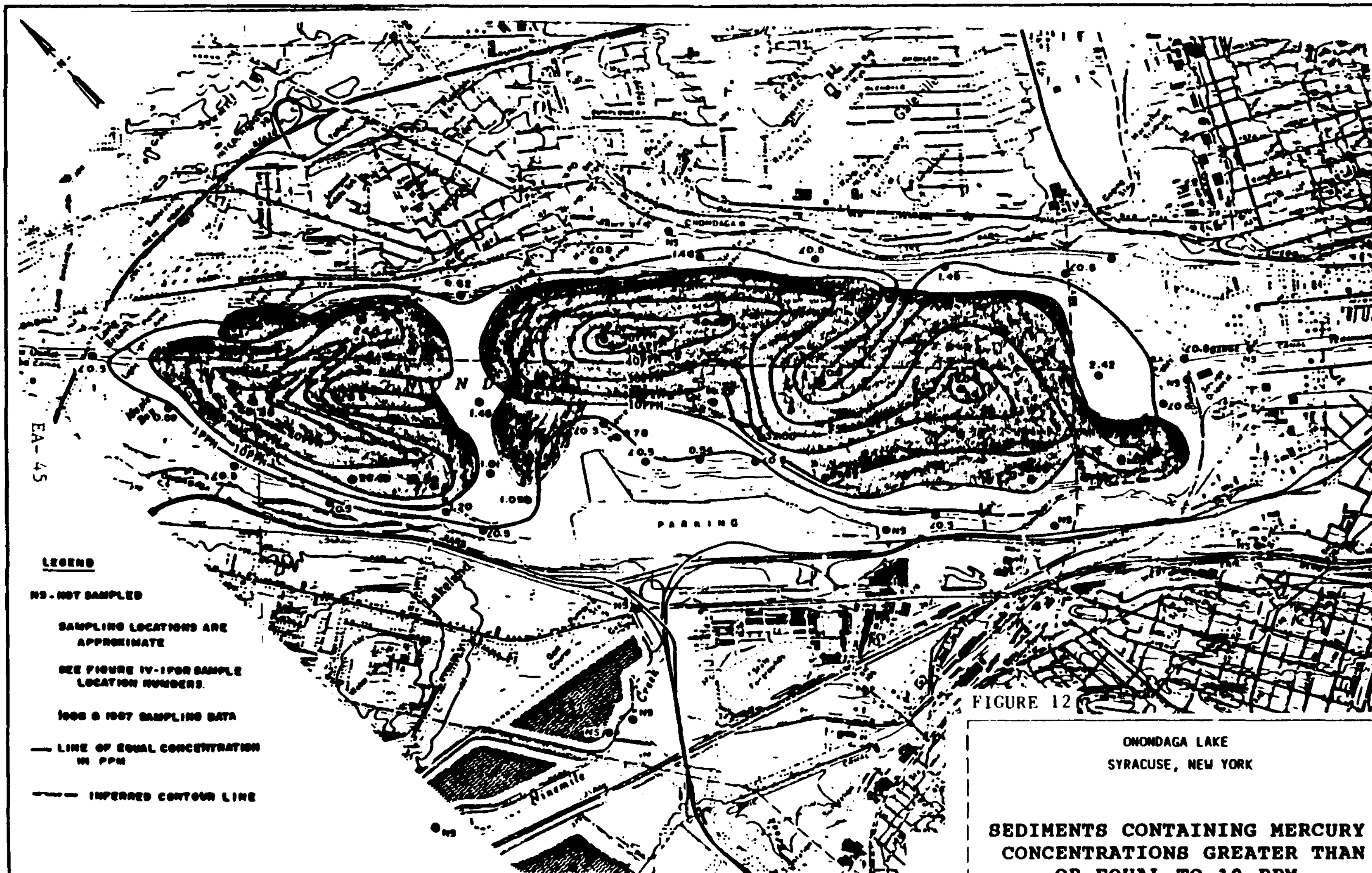


FIGURE 11

ONONDAGA LAKE
SYRACUSE, NEW YORK

SEDIMENTS CONTAINING MERCURY CONCENTRATIONS GREATER THAN OR EQUAL TO 5 PPM

U.S. ARMY ENGINEER DISTRICT, BUFFALO



LEGEND
NS - NOT SAMPLED
SAMPLING LOCATIONS ARE APPROXIMATE
SEE FIGURE IV-1 FOR SAMPLE LOCATION NUMBERS.
1986 & 1987 SAMPLING DATA
LINE OF EQUAL CONCENTRATION IN PPM
INFERRED CONTOUR LINE
PARKING
ONONDAGA
Ninemile
1PPM
10PPM
ONONDAGA LAKE
SYRACUSE, NEW YORK
SEDIMENTS CONTAINING MERCURY CONCENTRATIONS GREATER THAN OR EQUAL TO 10 PPM
U.S. ARMY ENGINEER DISTRICT, BUFFALO

FIGURE 12

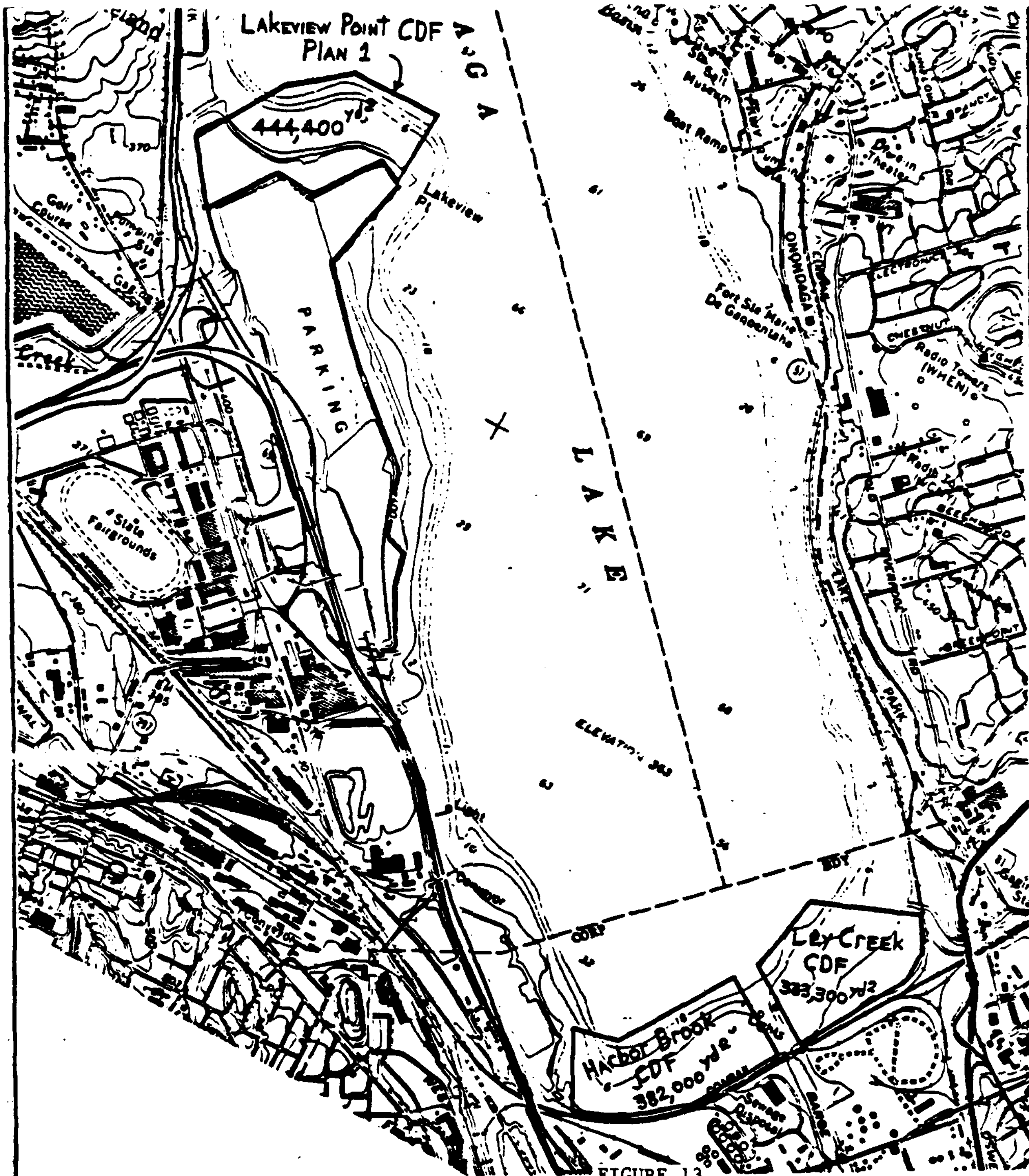


FIGURE 13

SCALE 1:24 000

0 1000 2000 3000 4000

CONTOUR INTERVAL 10 FEET

DEPTH CURVES AND SOUNDINGS IN FEET

DATUM IS 363 FEET IN ONONDAGA LAKE

MN GN 11½° 204 MILS 0°49' 15 MILS

ONONDAGA LAKE
SYRACUSE, NEW YORK

LOCATION OF LEY CREEK, HARBOR BROOK AND PLAN 1 CDF ALTERNATIVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO

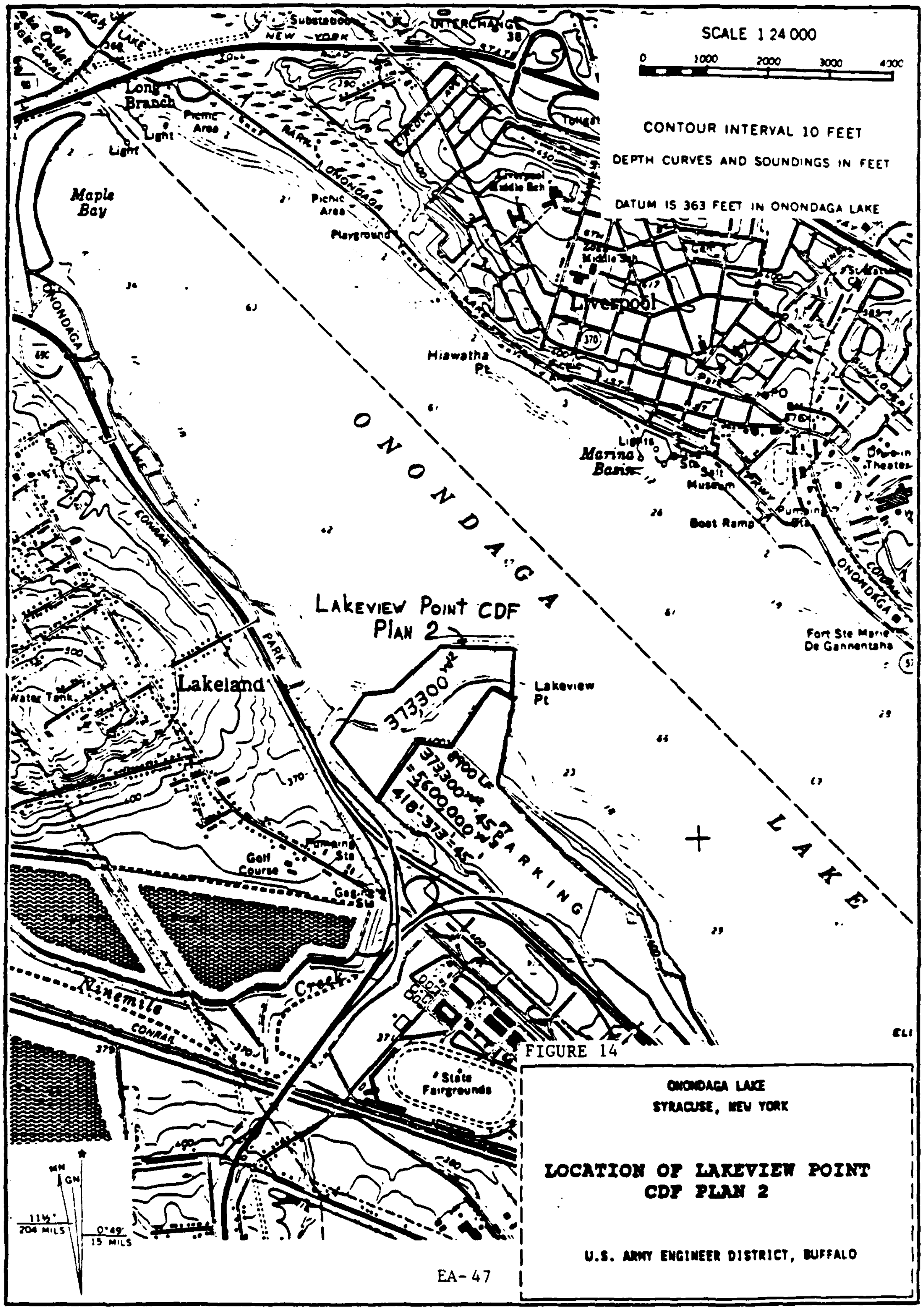


FIGURE 14

ONONDAGA LAKE
SYRACUSE, NEW YORK

LOCATION OF LAKEVIEW POINT CDF PLAN 2

U.S. ARMY ENGINEER DISTRICT, BUFFALO

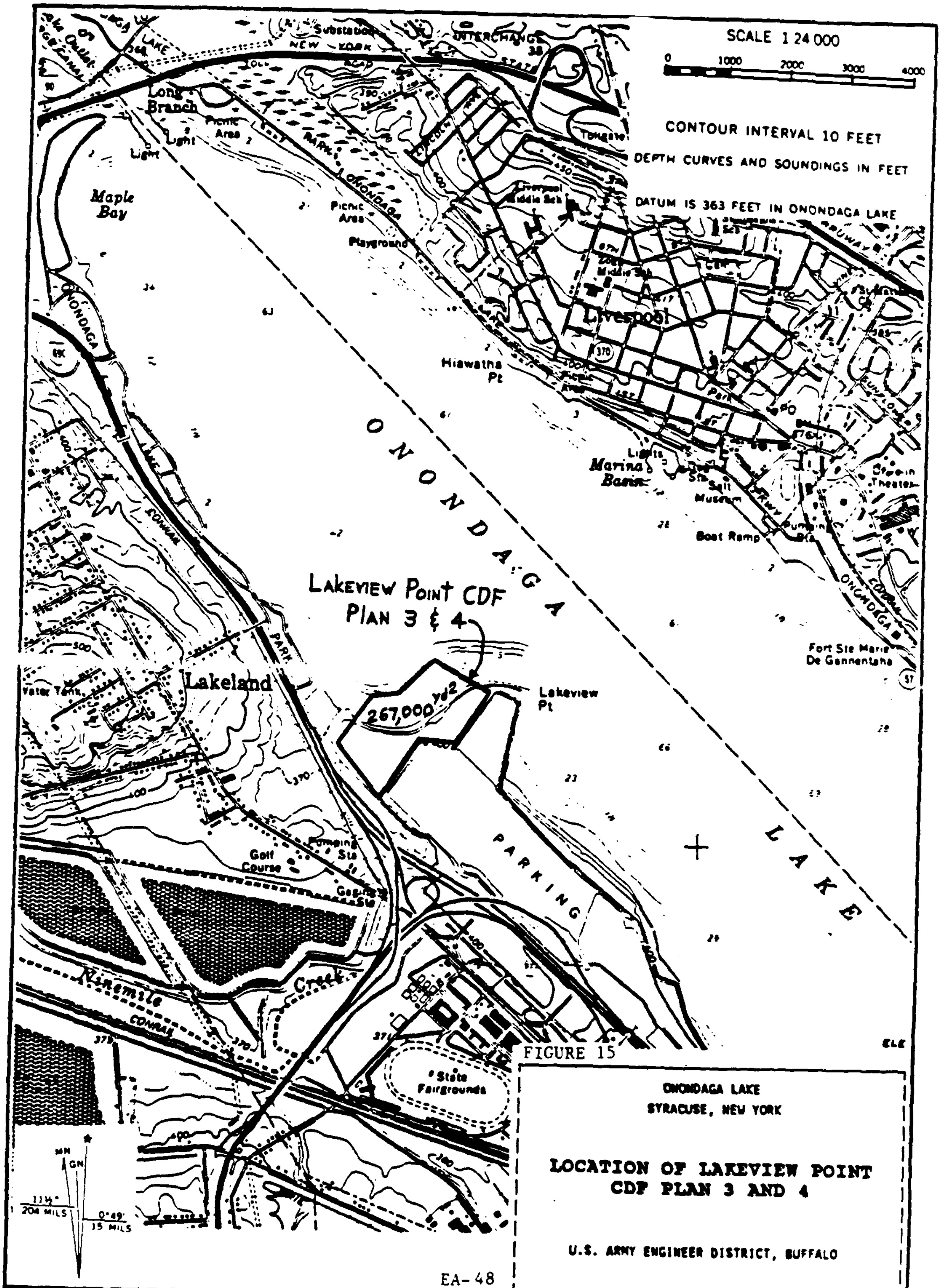


FIGURE 15

ONONDAGA LAKE
SYRACUSE, NEW YORK

LOCATION OF LAKEVIEW POINT CDP PLAN 3 AND 4

U.S. ARMY ENGINEER DISTRICT, BUFFALO

inactivation. Mixing of water bodies has the purpose of destratifying water bodies in order to eliminate the anaerobic reducing conditions in hypolimnetic waters and developing uniform profiles for parameters such as dissolved oxygen, temperature, and phosphorus. In the case of Onondaga Lake, mixing will not be considered because of the goals to be achieved, but will be replaced with hypolimnetic aeration. Nutrient inactivation has the purpose of removing nutrients from the biological cycles of water bodies in an attempt to reverse eutrophication. Phosphorus is generally the preferred target because of the greater probability of reducing its concentration to growth limiting proportions.

3.09 The first in-lake management measure being considered is the aeration of the hypolimnion during stratification to maintain dissolved oxygen concentrations near those observed at the beginning of the onset of stratification. This can be achieved by dissolving air or pure oxygen in the bottom waters. Because of the large amounts of oxygen needed and the low efficiency of air methods, use of pure oxygen will be investigated. The oxygen will change a reducing environment to an oxidizing environment, thereby reducing or eliminating the amounts of phosphorus, metals, hydrogen sulfide, and methane that leach and recycle from the sediments during anoxic conditions.

3.10 The second management measure is the use of alum to precipitate and remove large amounts of algae, bacteria, phosphorus, and sediment from the water. The immediate noticeable results would be a large reduction in the water column phosphorus concentration and a possible decrease in the amount of algae. This would only be a temporary measure and treatment would probably have to be performed at least twice a year because of the continuing inputs from METRO (Syracuse Sewage Treatment Plant), the tributaries, and bottom recycling if anoxic conditions persist during the summer.

f. Non-Point Sources Diversion/Sedimentation Measure

3.11 In the Tully Valley approximately 15 miles upstream of Onondaga Creek, solution salt mining has been carried out from the late 1800s thru the mid 1900s. Because of this, there has been some subsidence of the land in the area. A small stream as shown drains the hillside area to the west of the valley, south of Otisco Road. A small area in the valley thru which this creek flows has subsided causing a mud deposition area. Groundwater flowing thru the solution area in bedrock surfaces in this area causing a mud boil phenomenon. The creek flowing thru this area is clear before entering this area and muddy leaving afterwards. This creek then flows into Onondaga Creek. The water in Onondaga Creek above this confluence is clear. The mud boil field provides the sediment load to Onondaga Creek. Reference Figure 16.

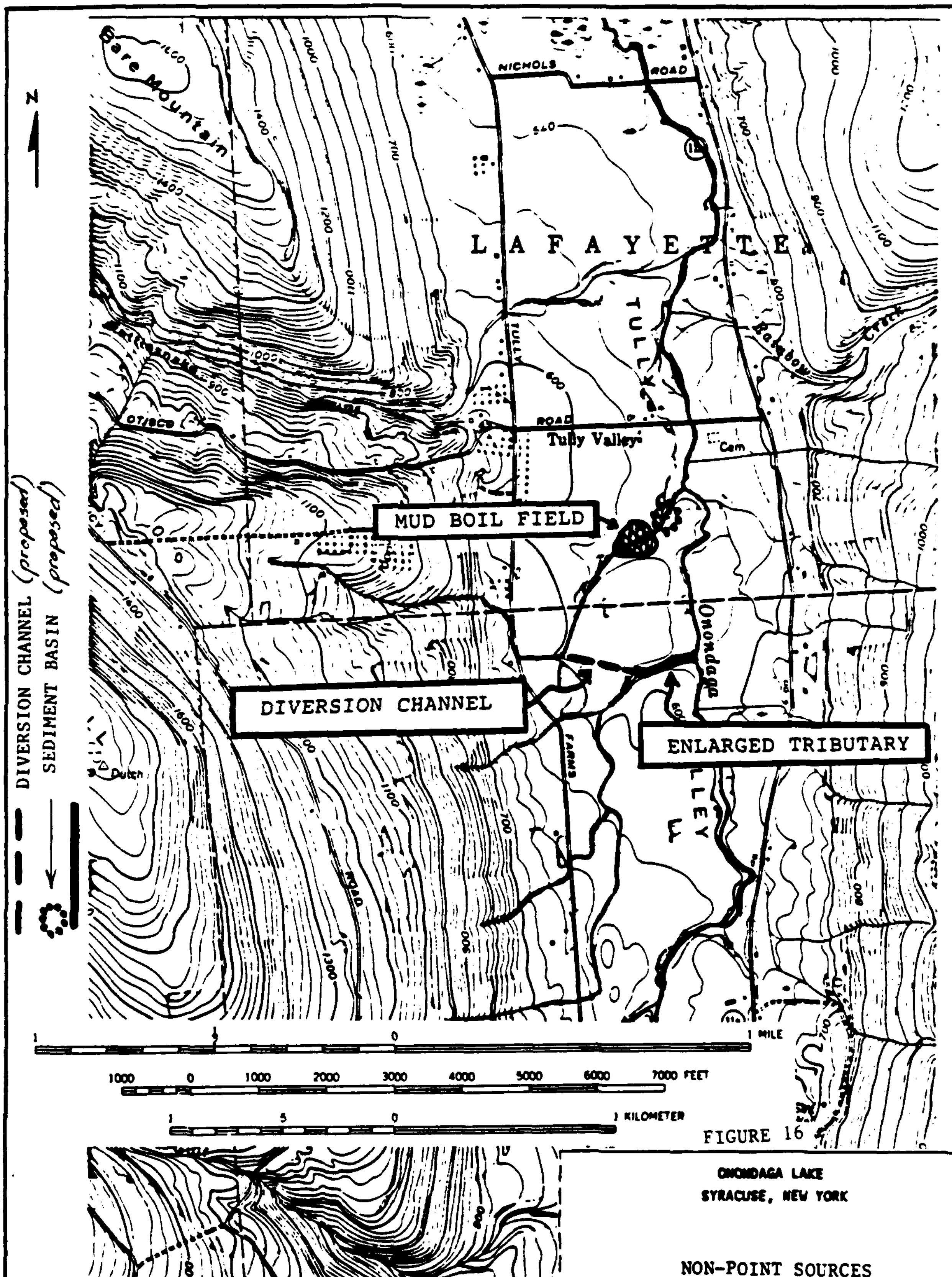


FIGURE 16

ONONDAGA LAKE
SYRACUSE, NEW YORK

NON-POINT SOURCES
(DIVERSION/SEDIMENTATION PLAN)

U.S. ARMY ENGINEER DISTRICT, BUFFALO

OTISCO VALLEY QUADRANGLE

3.12 The diversion measure proposes to divert the side creek water before it reaches the mud boil field to a creek to the south. The diversion channel would be approximately 1,200 feet in length and would be constructed thru farm fields. From the point of entrance of the diversion channel to this creek to its confluence with Onondaga Creek, the creek channel would be enlarged to handle the additional flow. The old cutoff creek would have local drainage and groundwater flow from the mud boil area. Below this area a settling basin would be constructed to clearify this flow before it reaches Onondaga Creek. Occasionally the settling basin would be dredged to clean it out with the material being appropriately deposited near by. It is expected that this material is common mud with a high chloride concentration.

OTHER MEASURES

a. METRO Sewage Treatment Plant

3.13 Other measures involving the METRO STP include investigation of various methods of phosphorus removal, ammonia removal, and nitrogen removal. Additional measures include the upgrading of the Ley Creek and Liverpool pump stations. Through the elimination of the bypasses at both pump stations and further reductions of overflows in the system, the result will be to reduce bacterial contamination and provide some reduction of the wet weather loadings of nutrients and biochemical oxygen demand.

b. Combined Sewer Overflow Treatment (CSO) and/or Diversion

3.14 The measures involving the combined sewer overflow treatment and/or diversion include the separation of the combined sewer system, centralized CSO transmission and treatment, and regional CSO transmission/treatment.

1. Separation of Combined Sewer System

3.15 The sewer separation would require the construction of a new sanitary sewer system and the conversion of the combined sewer system into storm sewers. Combined sewer overflows would be eliminated by virtue of eliminating combined sewers.

2. Regionalized CSO Collection and Treatment Facilities

3.16 This measure includes CSO transmission pipelines that would feed high rate CSO treatment facilities. Swirl concentrators have been found to provide the highest efficiencies for high rate facilities and as such have been selected as the treatment method. The facilities can incorporate either in-line or off-line storage to decrease the design treatment rate. These facilities would concentrate solids and some of the organic

matter in the flow and return it, via the underflow sewer to the local interceptor, which then transmits it to the METRO STP for treatment (Onondaga Lake or Seneca River discharge). The overflow from the swirl concentrator would be discharged to Onondaga Creek, Harbor Brook, or Ley Creek.

3. Centralized CSO Transmission and Treatment Facilities

3.17 The centralized concept has CSO transmission pipelines (intercepting all major CSO discharges within a basin) leading to three potential treatment alternatives:

a. High rate treatment facilities. The high rate treatment facility underflow would be discharged to either METRO or a CSO treatment facility. The overflow from the facility would be discharged to Onondaga Lake or the Seneca River.

b. In-water contaminant structures known as the flow balance method (FBM). FBM's would provide temporary storage of flow from the centralized CSO transmission pipelines with total pumpback to the METRO STP for treatment.

c. In-line Tunnel Storage. Storage tunnels would be constructed along the same corridors as the centralized pipelines but would differ in the fact that their diameter would be sized to store all of the flow generated during a design storm. Treatment would be provided at either METRO or a separate CSO treatment facility, with ultimate discharge to either the lake or the Seneca River.

ENVIRONMENTAL ENHANCEMENT CONSIDERATIONS

Community and Regional Development

3.18 Community and regional environmental enhancement considerations would be similar to those on-going developments, areas presently under study, and other development ideas that are being considered by local and regional planning agencies, as depicted in the previous Environmental Setting section under Community and Regional Growth. Reference Figure 17.

3.19 Potential for various development schemes would relate to the level of Lake water and sediment clean-up measures, and associated water and sediment quality conditions. While upland developments may be facilitated by generally improved environmental conditions (water quality) and aesthetics; realistic implementation of water and sediment contact activities and developments (i.e. swimming, beaches, boating, marinas, fishing) would require greater levels of investigation and clean-up measures; considering health and safety factors also. For example, development of a lake beach swimming area would require consistently safe water and sediment quality standards. In this

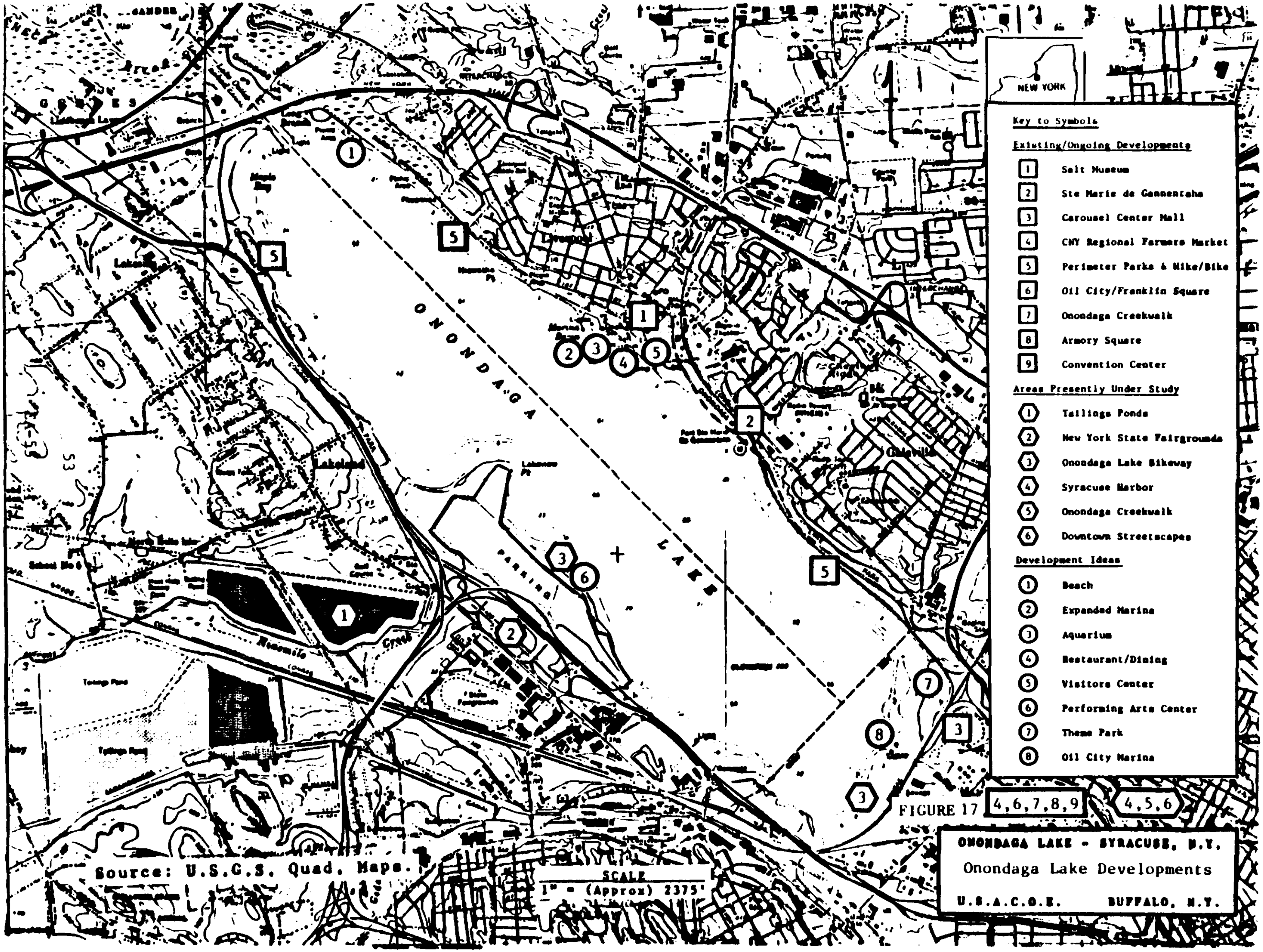


FIGURE 17

ONONDAGA LAKE - SYRACUSE, N.Y.
Onondaga Lake Developments
U.S.A.C.O.E. BUFFALO, N.Y.

case, conditions may warrant determination of additional safety standards. Implementation, in addition to water quality standards, would likely require dredging and disposal of polluted sediments and replacement with clean beach material. Measures to prevent infiltration or contamination by other pollution sources or sediments would also have to be considered.

3.20 Similar considerations and measures would likely have to be considered for marina and docking locations, and relative to fishing to prevent future contamination of fisheries from water and sediment contamination.

3.21 Lake development zoning may be desirable to control future desirable developments and environmental and health and safety conditions.

Natural Environmental Development

3.22 The following are potential preliminary enhancement considerations if water quality is improved in the Onondaga Lake System. These considerations would have to be further evaluated and coordinated by the Corps of Engineers, USFWS, and NYSDEC if the study is funded and authorized to continue into the next stage of the planning process.

1. At the northwest end of Onondaga Lake - just inland from the Lake's shoreline, within the general area identified as being "cut-and-fill-land" in the Soil Survey Report of Onondaga County (U.S.D.A. Soil Conservation Service, January 1977) - there are approximately five small low lying wooded scrub/shrub seasonally saturated areas separated from the lake by a higher narrow strip of land containing a laneway/recreation trail. These man-made low lying areas are also interspersed with aquatic plants. These low lying areas should be evaluated as to the feasibility of accomplishing access connections with the lake, in order to allow for seasonal flooding of vegetation by lake water during periods of higher lake water levels, as well as to provide vegetated shallow aquatic habitat that can be either seasonally or permanently accessed by warm water fish to use for spawning and/or feeding. It may be possible that northern pike could be attracted to these vegetated low lying areas to spawn during the early part of the spring season. These areas may also provide spawning and nursery habitat for some other warm water fish, such as bass and panfish, if adequate water levels are available in these areas during the later part of the spring season when water temperatures are higher. Further, if water levels can be dependably maintained (i.e. perhaps by installation of water level control structures) through the waterfowl nesting season, some contribution toward enhancement of breeding, feeding and brooding wetland habitat for waterfowl may also be provided;

2. Lacustrine emergent wetlands along the south and west shorelines of Onondaga Lake should be further evaluated as to potential for fisheries and wildlife habitat enhancement;

3. Consideration should be given as to the possibility of installing woodduck nest boxes, nest baskets and/or Canada goose nesting platforms in existing wetlands. Such nesting structures should be placed in locations that would have low potential for human disturbance.

4. Consideration should be given as to the possibility of establishing vegetation plantings where possible - particularly in locations were tributary streams containing trout have water areas that are more exposed to sunlight due to paucity or absence of riparian vegetation, or where streambanks are subject to erosion and siltation by run-off. Such plantings would eventually contribute toward enhancing fisheries habitat by providing shade as well as a source of detritus to the stream.

5. If a confined disposal facility (CDF) is chosen as a selected measure, upon completion of filling the site with polluted dredged material, the CDF should then be capped with clean fill material, in order to help decrease the potential for uptake of heavy metals and other contaminants into the wildlife food chain. Consideration should also be given as to the feasibility of constructing (as a part of the stone dike design) a narrow level shelf about four to eight feet below the anticipated normal water level of the Lake; then depositing clean gravel along the shelf for use by some warm water fish species as potential spawning habitat.

6. Consideration should be given to determining "the feasibility of enhancing seasonal flooding along the south side of Ley Creek up to the Conrail embankment and Wolf Street to provide spawning habitat for wildlife." (Reference: U.S. Fish and Wildlife Planning Aid Letter)

7. Evaluate the feasibility of depositing clean gravel material in some shallow littoral zone areas along the lake's perimeter, in order to enhance spawning habitat for some warm water fish species.

8. With regard to wetlands in the general vicinity of the lake's perimeter, evaluate the feasibility for establishing or improving long-term water connections to Onondaga Lake, in order to further enhance such aquatic habitat for fish and wildlife. (Reference: U. S. Fish and Wildlife Service Planning Aid Letter)

9. "Determine the feasibility of establishing, or re-establishing, emergent wetlands along the southern shore of the Lake". (Reference: U.S. Fish and Wildlife Service Planning Aid Letter)

SECTION 4 - ENVIRONMENTAL EFFECTS

INTRODUCTION

4.01 This section briefly compares anticipated environmental effects of the various measures under consideration, relative to the various environmental evaluation parameters and the No Action (without project conditions) alternative. It describes the anticipated impacts identified in the table entitled Generally Ancipated Impacts, which follows the Introduction and Summary of Assessment.

Table 8 - Summary Table (Costs)

Cost Estimate Summary of Measures, Onondaga Lake

Cost Estimate Summary of Measures

Measure Definition	Total First Cost $
1. Dredging of Onondaga Lake	
a. 6,500,000 Cubic Yards	61,700,000
b. 3,000,000 Cubic Yards	28,500,000
c. 2,000,000 Cubic Yards	19,100,000
1.1 Confined Disposal Facilities (Integral with dredging)	
a. Design 1 (Confine 6.5 million CY in 22' of water)	63,500,000
b. Design 2 (Confine 6.5 million CY in 6' of water)	50,700,000
c. Design 3 (Confine 3 million CY)	20,700,000
d. Design 4 (Confine 2 million CY)	17,500,000
1.2 Solidification of Contaminated Sediments ($80/CY) (Integral with dredging)	
a. 6,500,000 Cubic Yards	520,000,000
b. 3,000,000 Cubic Yards	240,000,000
c. 2,000,000 Cubic Yards	160,000,000
2. Capping of Contaminated Sediments (0.5 feet sand)	
a. < 1 ppm mercury	198,000,000
b. < 5 ppm mercury	162,000,000
c. < 10 ppm mercury	143,000,000
3. In-lake Treatment	
a. Aeration of the Hypolimnion	1,378,000
b. Chemical Treatment	12,000,000
4. Non-point Sources	
a. Mud Boils on Onondaga Creek	348,000
b. Waste Beds	N/A
5. Natural Development	10,000 - 400,000
6. Metro Sewage Treatment Plant	
a. Pump Station Upgrading and/or Expansion	N/A
b. Phosphorus, Ammonia, & Nitrogen Removal	N/A
c. Effluent Discharge Alternative	N/A
7. CSO Treatment or Diversion	
a. Best Management Plan	N/A
b. Regional CSO Treatment Facilities	
o Separation of Combined Sewer Systems	N/A
o Storage options	N/A
c. Centralized Treatment & Storage	
o High Rate Treatment Facilities	N/A
o In-water Contaminant Structures	N/A
o In-line Tunnel Storage	N/A

Table 9 · Generally Anticipated Impacts

Evaluation Parameters	No Action	Dredging, CDF-Disposal, Solidification	Capping of Contaminated Sediments	In-Lake Treatment Aeration Chemical	Non-Point Sources Onondaga Creek Settling Basin	Other Measures Pollution Control
	Measures					
Human (Man-Made) Environment						
Community &	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
Regional Growth	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Displacement	ST:Minor Adverse	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse
of People	LT:Minor Adverse	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Minor Adverse	LT:Not Significant
Displacement	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Minor Adverse	ST:Not Significant
of Farms	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Minor Adverse	LT:Not Significant
Business/Industry	ST:Minor Adverse	ST:Minor Beneficial	ST:Minor Beneficial	ST:Minor Beneficial	ST:Minor Beneficial	ST:Minor Beneficial
Employment/Income	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Recreation	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant
	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Public Facilities	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Moderate Beneficial
and Services	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial
Property Values	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
and Tax Revenue	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial	LT:Minor Beneficial
Noise and	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
Aesthetics	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial	LT:Minor Beneficial
Community	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse
Cohesion	LT:Minor Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Minor Beneficial
Cultural Resources	ST:Minor Adverse	ST:Minor Adverse	ST:Minor Adverse	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse
	LT:Minor Beneficial	LT:Minor Beneficial	LT:Minor Beneficial	LT:Not Significant	LT:Minor Beneficial	LT:Minor Beneficial
Natural Environment						
Air Quality	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Not Significant	ST:Moderate Adverse	ST:Not Significant
	LT:Not Significant	LT:Moderate Adverse	LT:Not Significant	LT:Not Significant	LT:Moderate Adverse	LT:Not Significant
Water Quality	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Major Beneficial	ST:Moderate Adverse	ST:Moderate Beneficial
	LT:Moderate Benefical	LT:Major Beneficial	LT:Major Beneficial	LT:Major Beneficial	LT:Moderate Adverse	LT:Moderate Beneficial
Plankton	ST:Not Significant	ST:Moderate Adverse	ST:Minor Adverse	ST:Moderate Beneficial	ST:Moderate Beneficial	ST:Moderate Beneficial
	LT:Not Significant	LT:Moderate Beneficial	LT:Minor Adverse	LT:Moderate Beneficial	LT:Moderate Adverse	LT:Moderate Beneficial
Benthos	ST:Not Significant	ST:Moderate Adverse	ST:Major Adverse	ST:Minor Adverse	ST:Moderate Adverse	ST:Major Beneficial
	LT:Not Significant	LT:Major Beneficial	LT:Major Beneficial	LT:Moderate Beneficial	LT:Moderate Adverse	LT:Major Beneficial
Fisheries	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Minor Adverse	ST:Moderate Adverse	ST:Moderate Beneficial
	LT:Not Significant	LT:Moderate Beneficial	LT:Major Beneficial	LT:Major Beneficial	LT:Major Beneficial	LT:Major Beneficial
Vegetation	ST:Not Significant	ST:Minor Adverse	ST:Minor Adverse	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse
	LT:Not Significant	LT:Not Significant	LT:Moderate Beneficial	LT:Moderate Beneficial	LT:Moderate Adverse	LT:Moderate Beneficial
Wildlife	ST:Not Significant	ST:Moderate Adverse	ST:Moderate Adverse	ST:Minor Beneficial	ST:Moderate Adverse	ST:Minor Beneficial
	LT:Not Significant	LT:Moderate Beneficial	LT:major Beneficial	LT:Moderae Beneficial	LT:Moderate Adverse	LT:Not Significant
Threatened &	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant	ST:Not Significant
Endangered Species	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant
Wetlands	ST:Not Significant	ST:Minor Adverse	ST:Moderate Adverse	ST:Not Significant	ST:Not Significant	ST:Not Significant
	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant	LT:Not Significant

ST = Short Term
LT = Long Term

Table 10A · No Action (Without Project Conditions)

Evaluation Parameter	Anticipated Impacts and Remarks
HUMAN (MAN MADE) RESOURCES	
Community and Regional Growth	ST: Minor Adverse LT: Minor Beneficial It is expected that point and non-point sources of pollution will be increasingly addressed. Some remedial actions may be taken to address Onondaga Lake water and sediment quality pollution problems to the extent of available and justifiable use of alternate resources. Water quality run-off would continue to gradually improve, if pollution control can keep up with urban growth. Lake water quality problems would likely persist for some time into the future, as pollution precipitate sediments are recycled back into the water. Upper level sediment quality may gradually improve as cleaner sediments cover more polluted sediments. Potential movement and/or mixing of polluted sediments would likely remain high. It is likely that water and particularly sediment quality will continue to be of great concern for some time into the future. Associated in-water type activities and developments (swimming, beaches, boating, marinas, fisheries, fishing, access) would be limited accordingly. Improved conditions would facilitate aesthetics and associated upland development plans (parks, hike/bike path,etc.).
Displacement of People	ST: Minor Adverse LT: Minor Adverse Swimming in the Lake was banned in 1940. In light of the existing and anticipated Lake water and sediment quality, it is anticipated that swimming may be banned indefinitely.
Displacement of Farms	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of farms or disruption of any farm activity or district.

Table 10A · : No Action (Without Project Conditions) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Business/Industry Employment/Income	ST: Minor Adverse LT: Minor Beneficial Industrial activity around the Lake has declined in recent history and continues to decline, but is beginning to stabilize. Generally, moderate growth in business, employment, and income is anticipated for the area. It is expected that point and non-point sources of pollution will be increasingly addressed. Some remedial actions may be taken to address Onondaga Lake water and sediment quality pollution problems to the extent of available and justifiable use of alternate resources. This will likely include pollution source interests resource input. Remedial actions may provide business, employment, and income opportunities for associated establishments periodically. It is likely that water and particularly sediment quality will continue to be of great concern for some time into the future. Associated in-water type activities and developments (swimming, beaches, boating, marinas, fisheries, fishing, access) and associated business, employment, and income opportunities would be limited accordingly. Improved conditions would facilitate aesthetics and associated upland plans (parks, concessions, restaurants, etc.) and associated business, employment, and income opportunities.
Recreation	ST: Not Significant LT: Minor Beneficial Demand for developments to facilitate recreational activities is expected to continue to be great in the project area particularly for activities such as: swimming, boating picnicking, hiking/biking, and tennis. Developments are being pursued to the extent possible. It is expected that water and particularly sediment quality will continue to be of great concern for some time into the future. Associated in-water type activities and development (swimming, beaches, boating, marinas, fisheries, fishing, access) would be limited accordingly. Improved conditions would facilitate aesthetics and associated upland plans (parks, bike path, etc.).

Table 10A : No Action (Without Project Conditions) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Public Facilities and Services	ST: Minor Adverse LT: Minor Beneficial It is expected that point and non-point sources of pollution will be increasingly addressed. Community sewage treatment plants are being upgraded. Some other limited remedial actions may be taken to address Onondaga Lake water and sediment quality pollution problems to the extent of available and justifiable use of alternate resources. It is likely that water and particularly sediment quality will continue to be of great concern for some time into the future. Associated in-water type activities and developments (swimming, beaches, boating, marinas, fisheries, fishing, access) would be limited accordingly. Improved conditions would facilitate aesthetics and associated upland development plans (parks, hike/bike path, etc.).
Property Values and Tax Revenue	ST: Not Significant LT: Minor Beneficial The Onondaga Lake vicinity is undergoing mixed redevelopment with increasing property values and associated tax revenues. Some limited remedial actions may be taken to address Onondaga Lake water and sediment quality pollution problems to the extent of available and justifiable use of alternate resources. It is likely that water and particularly sediment quality will continue to be of great concern for some time into the future. Associated in-water type activities and developments (i.e., swimming, beaches, boating, marinas, fisheries, fishing, access, etc.) would be limited accordingly. Likewise, real estate values and associated tax revenues. Some improved conditions would facilitate aesthetics and associated upland development plans (parks, hike/bike path, museums, restaurants, etc.) and associated area property values and associated tax revenues. Most of the immediate lake perimeter land would be expected to remain as county land.

Table 10A : No Action (Without Project Conditions) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Noise and Aesthetics	ST: Minor Adverse LT: Minor Beneficial It is expected that some remedial actions would be taken to address Onondaga Lake water and sediment quality pollution problems. This may involve construction and operation of construction equipment which would generate some noise and disrupt immediate construction area aesthetics, primarily for the short term. Gradually improved lake conditions would improve the aesthetics of the Lake and vicinity. In turn, some primarily upland developments or redevelopments (i.e., park facilities, hike/bike trail, museums, restaurants, etc.) may occur; which may involve construction and operation of construction equipment which would generate some noise and disrupt immediate construction area aesthetics; temporarily. Developments or redevelopments would alter lake vicinity aesthetics to some degree. No significant adverse long-term impacts would be expected.
Community Cohesion	ST: Minor Adverse LT: Minor Beneficial It is expected that Federal, State, and local entities will continue to work to resolve Onondaga Lake water and sediment quality problems and redevelopment plans into the future. Some conflicts pertaining to costs, responsibilities, problems, measures, impacts, effectiveness, clean-up needs, expediency, progress, etc. would be expected. Continued progress in clean-up of the lake and environment, will likely serve to pull community factions together toward a common goal.
CULTURAL RESOURCES	
Cultural Resources	ST: Minor Adverse LT: Minor Beneficial It is expected that Federal, State, and local entities will continue to work to resolve Onondaga Lake water and sediment quality problems and redevelopment plans into the future. Projects, particularly construction projects that could impact cultural resources, will need to be coordinated with cultural resource agencies for clearance and/or possibly mitigation measures. Although construction projects could disrupt cultural resource items, the required studies and/or coordination would facilitate cultural resources awareness and documentation.

Table 10A - No Action (Without Project Conditions) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
NATURAL RESOURCES	
· Air Quality	ST: Not Significant LT: Not Significant With this alternative, no Federal action would be taken to construct a project. Therefore, there would be no project related dust or exhaust emissions from construction work or construction equipment that could temporarily contribute to localized short-term degradation of air quality. Air quality in the near future in the general vicinity of Onondaga Lake would probably continue to be about the same as described for ambient conditions addressed previously in this environmental assessment. In the long-run, air quality may further improve if Federal and State standards are further upgraded and implemented.
· Water Quality	ST: Not Significant LT: Moderate Beneficial Water quality in the Lake may eventually improve in the future to some degree by natural means or as techniques to improve water quality are upgraded and implemented.
· Plankton	ST: Not Significant LT: Not Significant No disruption to existing phytoplankton and zooplankton populations would be anticipated, since no Federal action involving construction would occur. Annual occurrences of algal blooms in nutrient rich Onondaga Lake would probably continue to occur for some time into the future.
· Benthos	ST: Not Significant LT: Not Significant No disruption to existing benthic habitat and benthic organisms would be anticipated, since no Federal action involving construction would occur.
· Fisheries	ST: Not Significant LT: Not Significant No significant impact on fish habitat and fish species would be anticipated, since no Federal action involving construction would occur.
Vegetation	ST Not Significant LT Not Significant No significant impact on either aquatic or terrestrial vegetation would be anticipated, since no Federal action involving construction would occur.

Table 10A - No Action (Without Project Conditions) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
· Wildlife	ST: Not Significant LT: Not Significant No significant impact on either aquatic or terrestrial wildlife habitat or species would be anticipated, since no Federal action involving construction would occur.
· Threatened or Endangered Species	ST: Not Significant LT: Not Significant As indicated in a Planning Aid Letter dated 28 December 1990 prepared by the U.S. Fish and Wildlife Service and received by the Buffalo District Corps of Engineers on 31 December 1990, except for occasional transient individuals, no Federally listed or proposed endangered or threatened species are known to exist in the project impact area. Also, as indicated in a Coordination Letter from the New York State Department of Environmental Conservation dated 5 October 1990, their present file information did not identify any known occurrences of rare plants or animals or significant habitats on Onondaga Lake or within one mile of its shoreline.
· Wetlands	ST: Not Significant LT: Not Significant No significant impact on freshwater wetlands would be anticipated, since no Federal action involving construction would occur.

Table 10B : Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
HUMAN (MAN MADE) RESOURCES	
Community and Regional Growth	ST: Minor Adverse LT: *Moderate Beneficial* Project costs would likely be shared among Federal, State, local, and likely (in turn) pollution source interests; requiring associated resources (to be determined). Although dredging and disposal operations would be designed to minimize resuspension of sediments and pollutants, some resuspension will *likely unavoidably occur. Confined disposal facility* (CDF) construction and dredging and disposal operations would disrupt the existing improving lake environment (particularly pertaining to water quality) and community to some degree in the short-term. Dredging of polluted materials and disposal in a CDF (and possibly further solidification processes) would remove most of the sediment associated pollutants from the Lake system and processes containing them in the CDF. Assuming minimal further pollution sources, associated environmental quality improvements (primarily water and sediment quality and health and safety) would in turn facilitate desirable long-term community and regional growth activities and developments, such as: aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Some lake perimeter planning and development controls may even be desirable to protect for a long-term balanced desirable lake environment.
Displacement of People	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of people.
Displacement of Farms	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of farms or disruption of any farm activity or district.

Table 10B (Cont'd) : Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
Business/Industry Employment/Income	ST: Minor Beneficial LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would provide business, employment, and income opportunities for project work oriented establishments for a several year period. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in turn facilitate desirable long-term community and regional growth activities and developments and associated business, employment, and income opportunities associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc.
Recreation	ST: Not Significant LT: Moderate Beneficial It is not expected that this alternative would significantly adversely affect any existing (limited) recreational facilities or activities in the short-term, except perhaps temporary disruption to i.e., boating in immediate dredge activity areas and CDF construction areas. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in turn facilitate long-term potential for desirable recreational activities and developments associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc.
Public Facilities and Services	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would likely be a multi public and private effort. The project area is located in close proximity to the city of Syracuse and public facilities and services are expected to be sufficient to facilitate alternative implementation needs.

Table 10B (Cont'd) : Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
Public Facilities and Services (Cont'd)	Potential pollution sources (sewage treatment facilities, etc.) will need to be developed and maintained to acceptable levels. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and regional (public facilities and services) activities and developments associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Associated public facilities and services would need to be developed accordingly.
Property Values and Tax Revenues	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Associated property values and tax revenues would be expected to increase accordingly.
Noise and Aesthetics	ST: Minor Adverse LT: Moderate Beneficial Noise would be generated by the operation of construction equipment in the vicinity of the dredge operation and disposal facility. Noise generated by dredging operations in the shoreline vicinity may be disturbing in some cases (i.e, park areas) but would be transient and temporary. Assuming that the CDF facility would be constructed in the vicinity of the Solvay soda-ash disposal area (west side of Lake), the site is sufficiently remote from human noise sensitive areas that construction noise should not create a problem. No significant long-term adverse noise problems would be anticipated due to project implementation.

Table 10B (Cont'd) : Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
Noise and Aesthetics (Cont'd)	Lake area aesthetics would be temporarily disrupted due to the presents of dredging and construction equipment, dredging activities, and CDF construction activities. Some turbidity may be noticeable particularly in shallower areas due to dredging operations. Disposal facilities would be slightly enlarged along the west side of the Lake. The alternative would serve to improve environmental quality in the lake; including aesthetics and aesthetic related opportunities.
Community Cohesion	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely in-turn pollution source interests, requiring associated resources. Controversy pertaining to problems, needs, responsibilities, solutions, costs, etc. exist, but would be anticipated. Most interests agree that the Lake should be reasonable cleaned up and that a clean-up would be beneficial to the community and region. Many interests are working and cooperating to best resolve the situation. Successful reasonable multi-lateral clean-up of the Lake would significantly contribute to long term community cohesion and desirable community and regional growth efforts.
CULTURAL RESOURCES	
Cultural Resources	ST: Minor Adverse LT: Minor Beneficial It is not expected that implementation of this alternative would significantly adversely impact any significant cultural resources. However, some further cultural resources investigation and coordination would need to be conducted, pertaining to the areas to be dredged and the disposal site, in order to identify potential cultural resource sites, significance, potential impacts, and possibly mitigation measures, as necessary. Although construction could disrupt cultural resource items, the required studies and coordination would facilitate cultural resources awareness and documentation.

Table 10B - Dredging, CDF Disposal, Solidification (Option)
(Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
NATURAL RESOURCES	
- Air Quality	ST: Moderate Adverse LT: Moderately Adverse Operation of heavy equipment utilized to remove polluted bottom substrate from the Lake during dredging, construction of the CDF and, it selected as part of this alternative "solidification" of discharged dredged material in the CDF, would unavoidably cause some localized, short-term air quality degradation. Smoke, particulate emissions, combustion odors associated with expenditure of oil and fuel needed to operate equipment would be anticipated. Some temporary localized odor associated with resuspension of disrupted sediments to the water surface, and exposure of dredged organic material to the air environment would also occur. In order to help minimize resuspension of sediments, dredging would be performed in a manner and with equipment that would contribute toward limiting this adverse impact. If the "solidification" option was implemented on dredged contaminated material in the CDF as part of this alternative plan, no significant temporary impairment to air quality would be anticipated, since such treatment of the material would immobilize contaminants by binding them into a concrete-like, leach resistant mass.
- Water Quality	ST: Moderate Adverse LT: Major Beneficial Reference Table 31 in the Reconnaissance Report entitled "Evaluation of Lake Rehabilitation on Onondaga Lake and the Seneca River."
- Plankton	ST: Moderate Adverse LT: Moderately Beneficial Dredging activity would have a short-term adverse impact on phytoplankton and zooplankton in the general vicinity of the water column where such work is actively occurring. Temporary resuspension of pollutants as substrate materials are hauled up would also cause localized water agitation, that would contribute to increased turbidity and some short-term reduction in pyhtoplankton photosynthesis. Discharge of dredged material into the CDF site would

Table 10B - Dredging, CDF Disposal, Solidification (Option)
(Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
- Plankton (Cont'd)	eventually destroy all of the plankton organisms within the facility, as well as convert such aquatic habitat to terrestrial habitat. The area of such loss would depend on the size of the CDF site selected to be filled. The alternative CDF plans under consideration would convert the following approximate amounts of aquatic habitat in the Lake to terrestrial land: Plan #1 - 92 acres ±, Plan #2 - 77 acres ±; and Plans #3 and #4 - 55 acres ±. It is estimated that, localized disruption to plankton in the water column at the CDF site would occur over about 2-3 construction seasons while the stone dike is being built. Once the CDF dike is in place, there would likely be an additional 2-3 construction seasons of disruption to plankton in the Lake as well as in the CDF site until dredging was completed. If the "solidification" technique was applied to dredged material in the CDF, aquatic plankton habitat would still be lost. The conversion to a terrestrial environment would be a concrete-like mass.
- Benthos	ST: Moderate Adverse LT: Major Beneficial Dredging of mercury contaminated sediments from the Lake would directly result in excavation of existing benthic substrate over much of the Lake's area, with subsequent eventual destruction of any associated benthic macroinvertebrates inhabiting such removed substrate by deposition of dredged material into a CDF. Resettlement of silt and sediment that was temporarily put into suspension in the water column during active dredging, would also cover and smother a number of benthic organisms in the lake. Deposition of dredged material into the CDF site would cover over and destroy benthic organisms in the site. Eventually all aquatic benthic habitat would be lost in the CDF. Removal of mercury contaminated material from the Lake bottom and confinement of such material into a CDF, would expose cleaner benthic substrate for future recolonization by macroinvertebrates. Over time, a decrease in exposure to mercury contaminated sediment would likely mean less potential of passing on such a pollutant to higher tropic level aquatic organisms in the flood chain.

Table 10B (Cont'd) — Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
Benthos (Cont'd)	Depending on the CDF plan selected, the approximate amount of aquatic lake habitat that would eventually be permanently removed from use by aquatic macroinvertebrates would be similar to the areas indicated previously for the aforementioned plankton parameter. The approximate extent of the lake substrate area where sediments containing mercury concentrations are greater then (>) or equal to (=) 1 part per million (ppm), 5 ppm and 10 ppm are shown on Figures 10, 11, and 12 of this assessment. Depending on the mercury contaminated concentration area to be selected for dredging, over which existing benthic habitat and any associated benthic macroinvertebrates would be disrupted, the following estimated acreage in the Lake may be impacted: At mercury concentrations > or = 1 ppm - 2,610 acres ±, mercury concentrations or = 5 ppm - 2,140 acres and, at mercury concentrations > or = 10 ppm - 1,880 acres.
Fisheries	ST: Moderately Adverse LT: Moderately Beneficial Use of heavy equipment to place stone during construction of the CDF dike, as well as to dredge and discharge contaminated substrate into the CDF, would cause localized turbidity and disruption of the water column that would temporarily disturb warmwater fish in the general vicinity of such project activity. Such activity would probably temporarily aggravate gill systems of and result in short-term avoidance of active construction zones by these aquatic organisms. Although it is anticipated that dredging would be performed in a manner and with equipment that would help limit resuspension of sediments, some temporary resuspension of pollutants into the water column habitat utilized by fish would likely be unavoidable. Removal of most mercury contaminated substrate by dredging and confinement of such material would improve lake habitat to some degree for fish - particularly for bottom feeders. Depending on the CDF plan selected (including solidification), the approximate amount of lake habitat that would eventually be permanently removed from use by fish would be similar to the areas indicated previously for the aforementioned plankton parameter. Also, the approximate amount of

Table 10B (Cont'd) — *Dredging, CDF Disposal, Solidification (Option)*

Evaluation Parameter	Anticipated Impacts and Remarks
Fisheries (Cont'd)	fish habitat area in the Lake that would be beneficially impacted by dredging removal of mercury contaminated sediments, would be similar to the areas provided in the aforementioned benthos parameter. In the long-run, dredging and confinement of polluted dredged material would contribute toward providing a cleaner lake environment for fish.
Vegetation	ST: Minor Adverse LT: Not Significant Some existing terrestrial woody and herbaceous vegetation as well as filamentous algae and phytoplankton would probably be disrupted and/or destroyed during construction of the CDF site. Dredging and discharge of dredged material would cause some temporary disruption of filamentous algae and phytoplankton. If the solidification option of this alternative is not implemented, as discharged material settles above the waterline of the Lake, aquatic plants characteristic of damp soils (i.e., cattail), sedges, rush, reedgrass, etc.) would eventually be among the plant species invading the CDF. Over time, as the CDF was filed to capacity and the soils dried out further, more advanced stages of plant succession (i.e., shrubs, intolerant and tolerant trees, along with herbaceous plants more characteristic of terrestrial upland soils would establish on the site. However, if the dredged sediment was solidified, terrestrial plant invasion would probably be significantly hindered and delayed. The hardened cement-like substrate would probably be invaded by mosses and fungi, with some sporadic, sparse establishment of terrestrial plant species that may germinate in some low pockets of the CDF where wind-blown soils and organic litter accumulated. Depending on the CDF plan selected, about 55 to 92 acres of water area would be lost from potential use by aquatic plants. Conversely, a similar amount of upland habitat for terrestrial vegetation establishment could be gained in the future. However, since the CDF site would contain a concentration of polluted sediment, some uptake of pollutants by plants that established on the site would probably unavoidably occur, unless clean material could be obtained and used to cover over such sediment to a sufficient depth.

Table 10B - (Cont'd) : Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
Wildlife	ST: Moderately Adverse LT: Moderately Beneficial Heavy equipment activity associated with hauling and installation of stone to build the CDF dike, would temporarily discourage wildlife use of the lake area in the general vicinity where construction work was occurring. Some existing terrestrial wildlife habitat would be disrupted where the stone dike is "keyed" into bank terrain on the west shore. Depending on the CDF plan selected, about 55 to 92 acres of open water area would be removed from use by aquatic birds and mammals. Assuming that the solidification option to bind dredged sediment into a concrete-like leach resistant mass was not implemented, about 55 to 92 acres of terrestrial upland wildlife habitat would eventually be gained and established by vegetation - either by plantings, natural plant succession or a combination thereof. However, since the CDF site would contain polluted material, the quality of terrestrial habitat for wildlife would be diminished, unless clean soil material could be obtained and used to cover over such polluted material to a sufficient depth, in order to reduce potential for some contaminant uptake by vegetation, which in-turn may be utilized by wildlife as food. In the long run, dredging and confinement of polluted dredged material would significantly contribute toward providing a cleaner lake habitat environment for wildlife.
Threatened and Endangered Species	ST: Not Significant LT: Not Significant Similar statement as indicated for the No-Action alternative. Also, if a CDF site is selected, a biological field survey, if needed, would be coordinated with the USFWS and NYSDEC

Table 10B - (Cont'd) : Dredging, CDF Disposal, Solidification (Option)

Evaluation Parameter	Anticipated Impacts and Remarks
Wetlands	ST: Minor Adverse LT: Not Significant Dredging would occur in water of varying depths to about 60 feet ±, in a zone that has been identified as being a lacustrine lininetic open water area on the U.S. Fish and Wildlife Wetland Inventory Map. If a CDF site was selected for construction, the facility would be constructed in a part of the lacustrine limnetic deep water zone along the west shore near Lakeview Point. A part of the CDF would also extend into the shallower lacustrine littoral open water zone in about the same location. Although there is a small New York State Department of Environmental Conservation wetland (SYW10) about 5.5 acres in size located along the west bank of the Lake, about 200 feet south of the potential CDF sites under consideration, no significant adverse impact on this wetland is expected, although some minor sediment settlement may occur in the wetland from nearby construction during placement of dike stone

Table 10C : Capping of Contaminated Sediments

Evaluation Parameter	Anticipated Impacts and Remarks
HUMAN (MAN MADE) RESOURCES	
Community and Regional Growth	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Although placement of cover material would be designed to minimize resuspension of sediments and pollutants, some resuspension will likely unavoidably occur. Capping operations would disrupt the existing improving lake environment to some degree in the short-term. Transport and staging of large quantities of cover materials would be required. Capping of polluted sediments would isolate most of the sediment associated pollutants from the Lake system and processes containing them in the capped sediments. Assuming minimal further pollution sources, associated environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments, such as: aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Some lake perimeter planning and development controls may even be desirable to protect for a long-term balanced desirable lake environment.
Displacement of People	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of people.
Displacement of Farms	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of farms or disruption of any farm activity or district.

Table 10C : Capping of Contaminated Sediments (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Business/Industry Employment/Income	ST: Minor Beneficial LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would provide business, employment, and income opportunities for project work oriented establishments for a several year period. Alternative associated long term environmental quality improvements (primarily water and sediment quality and health and safety) would in turn facilitate desirable long term community and regional growth activities and developments and associated business, employment, and income opportunities associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc.
Recreation	ST: Not Significant LT: Moderate Beneficial It is not expected that this alternative would significantly adversely affect any existing (limited) recreational facilities or activities in the short term, except perhaps temporary disruption to i.e., boating in immediate capping material placement activity areas. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in turn facilitate long term potential for desirable recreational activities and developments associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc.
Public Facilities and Services	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would likely be a multi public and private effort. The project area is located in close proximity to the city of Syracuse and public facilities and services are expected to be sufficient to facilitate alternative implementation needs. Transport and staging of large quantities of cover materials would be required.

Table 10C   Capping of Contaminated Sediments (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Public Facilities and Services (Cont'd)	Potential pollution sources (sewage treatment facilities, etc.) will need to be developed and maintained to acceptable levels. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and regional (public facilities and services) activities and developments associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Associated public facilities and services would need to be developed accordingly.
Property Values and Tax Revenues	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments associated with aesthetics, parks, swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Associated property values and tax revenues would be expected to increase accordingly.
Noise and Aesthetics	ST: Minor Adverse LT: *Moderate Beneficial* Noise would be generated by the operation of construction equipment in the vicinity of the transport, staging, and cover material placement areas. Noise generated by placement operations in the shoreline vicinity may be disturbing in some cases (i.e., park areas) but would be transient and temporary. Assuming that the staging area would be located in the vicinity of the Solvay soda-ash disposal area (west side of Lake) the site is sufficiently remote from human noise sensitive areas that construction noise should not create a problem. *No significant* long-term adverse noise problems would be anticipated due to project implementation.

Table 10C   : Capping of Contaminated Sediments (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Noise and Aesthetics (Cont'd)	Lake area aesthetics would be temporarily disrupted due to the presents of construction equipment and activity. Some turbidity may be noticeable particularly in shallower areas due to capping operations. Some perimeter Lake surface area may *be converted to upland area with placement of capping* materials. The alternative would serve to improve environmental quality in the Lake; including aesthetics and aesthetic related opportunities.
Community Cohesion	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely in-turn pollution source interests, requiring associated resources. Controversy pertaining to problems, needs, responsibilities, solutions, costs, etc. exist, but would be anticipated. Most interests agree that the Lake should be reasonable cleaned up and that a clean-up would be beneficial to the community and region. Many interests are working and cooperating to best resolve the situation. Successful reasonable multi-lateral clean-up of the Lake would significantly contribute to long-term community cohesion and desirable community and regional growth efforts.
CULTURAL RESOURCES	
Cultural Resources	ST: Minor Adverse LT: Minor Beneficial It is not expected that implementation of this alternative would significantly adversely impact any significant cultural resources. However, some further cultural resources investigation and coordination would need to be conducted, pertaining to staging areas and areas to be capped, in order to identify potential cultural resource sites, significance, potential impacts, and possibly mitigation measures, as necessary. Although construction could disrupt cultural resource items, the required studies and coordination would facilitate cultural resources awareness and documentation.

Table 10C : Capping of Contaminated Sediments (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
NATURAL RESOURCES	
· Air Quality	ST: Moderate Adverse LT: Not Significant Operation of heavy equipment utilized to haul and place clean unpolluted capping material would unavoidably cause some localized short-term air quality degradation. Smoke, particulate emissions and combustion odors associated with expenditure of oil and fuel needed to operate equipment would be anticipated.
· Water Quality	ST: Moderate Adverse LT: Major Beneficial Reference Table 31 in the Reconnaissance Report entitled "Evaluation of Lake Rehabilitation on Onondaga Lake and the Seneca River."
· Plankton	ST: Minor Adverse LT: Not Significant Placement of clean unpolluted capping material such as sand, gravel, and armor stone, would cause localized temporary turbidity that could disrupt some phytoplankton and zooplankton in the water column where such work is actively occurring. Disruption of substrate would probably resuspend some pollutants into the the water column, which in-turn may accumulate to some degree in plankton. Once capping was completed, it would provide the isolation necessary to control movement of contaminants out of the polluted substrate material and into the overlying water column. Also, capping would prevent direct contact between aquatic biota - such as plankton - and contaminated sediment.
· Benthos	ST: Major Adverse LT: Major Beneficial Capping would smother and destroy existing benthic macroinvertebrates over a range of from 1,800 to about 2,610 acres of lake bottom substrate. Once capping was completed, it would prevent direct contact between aquatic biota - such as benthic organisms reestablishing on the surface of the newly deposited capping material - and contaminated sediment. The newly deposited material would provide a cleaner substrate habitat for reestablishment of macroinvertebrates. Over time, a decrease in exposure to mercury contaminated sediments could mean less potential of passing on such a pollutant to higher trophic level aquatic organisms in the food chain.
· Fisheries	ST: Moderate Adverse LT: Major Beneficial Capping construction work would temporarily disrupt the existing water column and benthic substrate habitat containing food organisms such as plankton and macroinvertebrates. Increased turbidity and water disruption during construction would cause fish to temporarily avoid localized areas in the lake where capping was actively underway. Short-term increase in silt, sediment and detritus in the water column associated with deposition of capping material and disruption of bottom substrate may temporarily aggravate gill systems of some fish. Once capping was completed, it would significantly reduce potential for direct contact between fish and aquatic biota in contaminated sediment and, would provide the isolation necessary to control movement of contaminants out of the polluted lake bottom substrate into the overlying water column utilized by fish. Clean unpolluted sand, gravel, or armor stone capping material would provide cleaner improved habitat quality for fish in the Lake. Armor stone placed in water depths less than 15 feet would contribute toward providing protective hiding and feeding habitat (on which algae and macro-invertebrates could be found), as well as firm habitat on which to attach egg masses by some fish species. Gravel placed in the shallow littoral zone may also provide spawning habitat for warmwater panfish in the Lake.
· Vegetation	ST: Minor Adverse LT: Moderate Beneficial Increased turbidity caused during deposition of capping material would contribute toward further reduction of sunlight penetration into the water, that could temporarily decrease the rate of submerged aquatic plant photosynthesis in the Lake, as well as within the shallow water zones of the tributary stream mouths. If submerged aquatic plants are present in the capping zone, such plants would be destroyed by covering. In the long-run, the deposited capping substrate would provide a cleaner habitat for establishment of some species of submerged rooted aquatic plants, and would decrease potential for exposure of mercury contaminated sediments of such aquatic vegetation.

Table 10C - Capping of Contaminated Sediments (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Wildlife	ST: Moderate Adverse LT: Major Beneficial Since capping would help isolate and control movement of contaminants from the existing sediment substrate in the Lake into the overlying water column, the quality of the aquatic environment would eventually be improved for use by wildlife - especially aquatic wildlife (i.e., seagulls, waterfowl, amphibians).
Threatened and Endangered Species	ST: No Significant Impact LT: No Significant Impact Similar statement as indicated for the no action alternative. Also, if capping is chosen as the selected alternative plan, continued coordination with the USFWS and NYSDEC would be conducted to determine if any further biological field surveys are needed.
Wetlands	*ST: Moderate Adverse* LT: Not Significant Capping construction work would cause some temporary increased short-term water turbidity that would resuspend some silt, sediment, and detritus as well as pollutants into the water column. Some of this material would probably settle out onto submerged plants in the littoral zone of the lake as well as peripheral wetlands which may cover a minor amount of such vegetation. Otherwise no significant adverse long-term impact would be anticipated.

Table 10D : In-Lake Treatment

Evaluation Parameter	Anticipated Impacts and Remarks
HUMAN (MAN MADE) RESOURCES	
Community and Regional Growth	ST: Minor Adverse LT: Moderate Beneficial Alternative costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation may disrupt or at least appear to disrupt the existing improving lake environment (particularly pertaining to water quality) and community to some degree in the short-term and periodically. Alternative implementation, would serve to improve Lake water quality (i.e., oxygenation, stratification, chemical precipitate removal) in the short and long-term. Alternative associated environmental quality improvements (water quality) would in-turn facilitate desirable long-term community and regional growth activities and developments, such as: aesthetics, parks, boating, marinas and services, and possibly swimming beaches, fishing and access and supplies etc. Some lake perimeter planning and development controls may even be desirable to protect for a long-term balanced desirable lake environment.
Displacement of People	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of people.
Displacement of Farms	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement of farms or disruption of any farm activity or district.

Table 10D : In-Lake Treatment (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Business/Industry Employment/Income	ST: Minor Beneficial LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would provide business, employment, and income opportunities for project work oriented establishments for a several year period. Alternative associated long-term environmental quality improvements (primarily water quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments and associated business, employment, and income opportunities associated with aesthetics, parks, boating, marinas and services, and possibly swimming, beaches, fishing and access and supplies, etc.
Recreation	ST: Not Significant LT: Moderate Beneficial It is not expected that this alternative would significantly adversely affect any existing (limited) recreational facilities or activities in the short term, except perhaps temporary disruption to i.e., boating in immediate treatment areas Alternative associated long-term environmental quality improvements (primarily water quality and health and safety) would in turn facilitate long-term potential for desirable recreational activities and developments associated with aesthetics, parks, boating, marinas and services, and possible swimming, beaches, fishing and access and supplies, etc.
Public Facilities and Services	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would likely be a multi public and private effort. The project area is located in close proximity to the city of Syracuse and public facilities and services are expected to be sufficient to facilitate alternative implementation needs.

Table 10D : In-Lake Treatment (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Public Facilities and Services (Cont'd)	Potential pollution sources (sewage treatment facilities, etc.) will need to be developed and maintained to acceptable levels. Alternative associated long-term environmental quality improvements (primarily water quality and health and safety) would in-turn facilitate desirable long-term community and regional (public facilities and services) activities and developments associated with aesthetics, parks, boating, marinas and services, possibly swimming, beaches, fishing and access and supplies, etc. Associated public facilities and services would need to be developed accordingly.
Property Values and Tax Revenues	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative associated long-term environmental quality improvements (primarily water quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments associated with aesthetics, parks, and possible swimming, beaches, boating, marinas and services, fishing and access and supplies, etc. Associated property values and tax revenues would be expected to increase accordingly.
Noise and Aesthetics	ST: Minor Adverse LT: Moderate Beneficial Noise would be generated by the operation of treatment plants and equipment in treatment vicinities; probably in north and south Lake basin center areas. This would not be expected to be a problem. No significant long-term adverse noise problems would be expected due to alternative implementation. Some turbidity may be noticeable in the lake treatment areas during and soon after treatment operations. Aeration measures would consider measures to avoid or minimize resuspension of polluted sediments.

Table 10D : In-Lake Treatment (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Noise and Aesthetics (Cont'd)	The alternative would serve to improve environmental quality (water quality) in the Lake; including long-term aesthetic and aesthetic related opportunities.
Community Cohesion	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely in-turn pollution source interests, requiring associated resources. Controversy pertaining to problems, needs, responsibilities, solutions, costs, etc. exist, but would be anticipated. Most interests agree that the Lake should be reasonable cleaned up and that a clean-up would be beneficial to the community and region. Many interests are working and cooperating to best resolve the situation. Successful reasonable multi-lateral clean-up of the Lake would significantly contribute to long-term community cohesion and desirable community and regional growth efforts.
CULTURAL RESOURCES	
Cultural Resources	ST: Not Significant LT: Not Significant It is not expected that implementation of this alternative would significantly adversely impact any significant cultural resources. It is not expected that any significant additional cultural resources studies will be necessary for this alternative, since it is not expected that any lake bottom, terrestrial ground, or structures would be significantly disrupted to implement the alternative.
NATURAL RESOURCES	
Air Quality	ST: Not Significant LT: Not Significant This water aeration technique is not expected to degrade air quality in the general vicinity of Onondaga Lake. No significant adverse impact is anticipated, since the liquid oxygen system would be stored in air tight tanks on-shore and, the liquid oxygen would be converted to a gas that would be forced along a hose to diffusers placed in the lake bottom.

Table 10D - In Lake Treatment (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Water Quality	ST: Major Beneficial LT: Major Beneficial Reference Table 31 in the Reconnaissance Report entitled "Evaluation of Lake Rehabilitation on Onondaga Lake and Seneca River."
Plankton	ST: Moderate Beneficial LT: Major Beneficial Since there are likely a number of factors that affect plankton populations in *Onondaga Lake*, improved aeration of the hypolimnion could also be a contributing factor toward eventually increasing diversity and expanding habitat use by phytoplankton and/or zooplankton in deeper waters of this Lake. Minor disruption of existing plankton above the hypolimnion due to some possible fine non-dissolved bubble movement through the water column. There are likely a number of factors that influence existing plankton populations and distribution in Onondaga Lake. It is possible that improvement in aeration of the hypolimnion of the Lake may also be a factor that contributes toward expansion of aquatic habitat use increased diversity and increased or decreased biomass of some zooplankton and phytoplankton organisms in water below the thermocline.
Benthos	ST: Minor Adverse LT: Moderate Beneficial Some *minor temporary* disruption of benthic habitat substrate and would likely occur, where mechanisms such as bubble diffusers and pipes are placed along the Lake bottom. Improved oxygenation of the hypolimnion would help *improve water quality* in the vicinity of the Lake bottom for macroinvertebrates.
Fisheries	ST: Minor Adverse LT: Major Beneficial During installation of pipes, diffuser tubes and sparing rafts, some short-term minor disruption of the water column would cause temporary avoidance of the work zone by warmwater fish presently inhabiting the lake. During much of the year, use of the hypolimnetic zone in the Lake is unavailable for utilization by fish inhabiting Onondaga Lake, due to lack of or significantly low oxygen levels. If properly designed, use of artificial aeration would help destratify water in the Lake, as well as allow *dissolved oxygen to be more uniformly distributed*. Improved long-term oxygenation in the hypolimnion would allow use of this deeper cooler lake environment by fish - particularly for eventual use by coldwater fish species. As aquatic *habitat* in the hypolimnion becomes more available for use by fish, some increase in the population and diversity of fish species may occur in the Lake - which would include piscivorous species that feed on smaller planktivorous fish

Table 10D - In Lake Treatment (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Vegetation	ST: Not Significant LT: Moderate Beneficial Improved oxygenation of the hypolimnion could influence growth and establishment of submerged rooted and/or floating aquatic plants in some areas of the Lake, if water turbidity decreases and deeper sunlight penetration into the water occurs.
Wildlife	ST: Minor Beneficial LT: Moderate Beneficial As utilization of the oxygenated hypolimnion becomes more available for use by fish, and if submerged aquatic plants are positively influenced by such oxygenation in this water zone such that biomass of edible vegetation and food organisms (i.e., invertebrates clinging to such vegetation) increases, habitat for aquatic birds (i.e., diving ducks) could be *improved* to some degree.
Threatened and Endangered Species	ST: Not Significant LT: Not Significant *Similar statement as indicated for the No Action* alternative. Also, if Lake Treatment is chosen as the selected alternative plan, further coordination with the USFWS and NYSDEC would be conducted to determine if further biological surveys are *needed*
Wetlands	ST: Not Significant LT: Not Significant If the In-Lake Treatment Alternative was implemented, no significant adverse impact on any known wetlands in the general vicinity of Onondaga Lake would be expected.

Table 10E : Non Point Sources, Onondaga Creek (Settling Basin and Diversion)

Evaluation Parameter	Anticipated Impacts and Remarks
HUMAN (MAN MADE) RESOURCES	
Community and Regional Growth	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Existing stream regime and land use would be altered slightly in the immediate project area by alternative implementation. Alternative implementation and maintenance would result in substantial reduction in sediment and chloride load to Onondaga Creek and in-turn Onondaga Lake. Associated environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments, such as: aesthetics, parks, swimming, boating, marinas and services, and possibly beaches, fishing and access and supplies, etc. Some lake perimeter planning and development controls may even be desirable to protect for a long-term balanced desirable lake environment.
Displacement of People	ST: Minor Adverse LT: Minor Adverse No houses would need to be acquired for implementation of the alternative. Several acres of land would need to be acquired to facilitate associated project features. Acquisition of land would at a minimum be in accordance with the "Uniform Relocation Assistance and Real Property Acquisition Policies Act," as amended.
Displacement of Farms	ST: Minor Adverse LT: Minor Adverse Alternative implementation would disrupt several acres of farmland including some containing prime soil types. Alternative implementation would require acquisition of several acres of farmland including some containing prime soil types to accommodate alternative project features.

Table 10E : Non Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Business/Industry Employment/Income	ST: Minor Beneficial LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would provide business, employment, and income opportunities for project work oriented establishments for a several year period. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in turn facilitate desirable long term community and regional growth activities and developments and associated business, employment, and income opportunities associated with aesthetics, parks, swimming, boating, marinas and services, and possibly beaches, fishing and access and supplies, etc.
Recreation	ST: Not Significant LT: Moderate Beneficial It is not expected that this alternative would significantly adversely affect any existing recreational facilities or activities. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate long-term potential for desirable recreational activities and developments associated with aesthetics, parks, swimming, boating, marinas and services, and possibly beaches, fishing and access and supplies, etc.
Public Facilities and Services	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source interests; requiring associated resources (to be determined). Alternative implementation would likely be a multi public and private effort. The project area is located in proximity to the city of Syracuse and public facilities and services are expected to be sufficient to facilitate alternative implementation needs.

Table 10E : Non-Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Public Facilities and Services (Cont'd)	Potential pollution sources (sewage treatment facilities, etc.) will need to be developed and maintained to acceptable levels. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn facilitate desirable long-term community and developments associated with aesthetics, parks, swimming, boating, marinas and services, and possibly swimming, fishing and access and supplies, etc. Associated public facilities and services would need to be developed accordingly. A local agency, would likely be required to maintain the project.
Property Values and Tax Revenues	ST: Minor Adverse LT: Minor Beneficial Project costs would likely be shared among Federal, State, local, and likely (in-turn) pollution source *interests; requiring associated resources* (to be determined). Existing stream regime and land use would be altered slightly in the immediate project area by alternative implementation. Alternative associated long-term environmental quality improvements (primarily water and sediment quality and health and safety) would in-turn *facilitate desirable* long-term community and regional growth activities and developments associated with aesthetics, parks, swimming, boating, marinas and services, and possibly beaches, fishing and access and supplies, etc. Associated property values and tax revenues would be expected to increase accordingly.
Noise and Aesthetics	ST: Minor Adverse LT: Minor Beneficial Noise would be generated by the operation of construction equipment in the immediate project area during construction of the diversion and enlarged channel sections and the sediment basin and disposal area. Since the project area is rural and generally isolated, it is not expected that construction noise would create a problem.

Table 10E : Non Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Noise and Aesthetics (Cont'd)	Noise would be generated periodically by the operation of construction equipment when sediments are removed from the settling basin and deposited in the nearby disposal facility/area. Since the project area is rural and generally isolated, it is not expected that maintenance noise would create a problem. The alternative project construction and maintenance area aesthetics would be altered by the presence of construction equipment, and project feature construction, and periodic maintenance operations; from rural farmland characteristics to project feature characteristics. The alternative would serve to improve environmental quality (primarily water quality) in the creek and lake; including aesthetic and aesthetic related opportunities.
Community Cohesion	ST: Minor Adverse LT: Moderate Beneficial Project costs would likely be shared among Federal, State, local, and likely in turn pollution source interests, requiring associated resources. Controversy pertaining to problems, needs, responsibilities, solutions, costs, etc. exist, but would be anticipated. Most interests agree that the creek and lake should be reasonable cleaned up and that a clean-up would be beneficial to the community and region. Many interests are working and cooperating to best resolve the situation. Successful reasonable multi lateral clean-up of the Lake would significantly contribute to long term community cohesion and desirable community and regional growth efforts.

Table 10E : Non-Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
CULTURAL RESOURCES	
Cultural Resources	ST: Minor Adverse LT: Minor Beneficial It is not expected that implementation of this alternative would significantly adversely impact any significant cultural resources. However, some further cultural resources investigation and coordination would need to be conducted, pertaining to the diversion channel, setting basin, and staging and disposal area, in order to identify potential cultural resource sites, significance, potential impacts, and possibly mitigation measures, as necessary. Although construction could disrupt cultural resource items, the required studies and coordination would facilitate cultural resources awareness and documentation.
NATURAL RESOURCES	
Air Quality	ST: Moderate Adverse LT: Moderate Adverse Heavy equipment activity during construction of the diversion channel, settling basin trap and tributary enlargement, as well as during monthly dredging and hauling of accumulated material from the sediment basin to an upland disposal site would cause localized, temporary, short-term air quality degradation. At the time work is occurring, dust from terrestrial soil disruption, smoke, particulate emissions a well as some combustion odors associated with expenditure of oil and fuel needed to operate construction equipment would occur.
Water Quality	ST: Moderate Adverse LT: Major Beneficial Although measures would be taken to help minimize water turbidity in the project locale caused during construction of the project, some unavoidable, temporary, short-term turbidity from soil and detritus disruption would still be anticipated whenever dredging of accumulated sediments was underway. Disturbed terrestrial soils would be promptly mulched and seeded in order to minimize soil erosion and dust. Reference statements on potential long term water quality improvement as addressed in the Reconnaissance Report matrix for this parameter.

Table 10E : Non-Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Plankton	ST: Moderate Adverse LT: Moderate Beneficial Additional short-term increased disturbance to plankton in downstream areas of Onondaga Creek and in the general vicinity of the creek's mouth would occur from turbidity during construction of this alternative plan, until disrupted soils in the upstream project zone stabilized and terrestrial exposed soils were mulched and seeded. In the long-run, there would be a long term contribution toward improved planktonic habitat in the southern basin of the Lake by reduction or elimination of silt into this water area from mud boils. Also, improved water clarity could be a contributing factor toward influencing population numbers diversity and/or distribution of some species of phytoplankton and zooplankton in this Lake locale.
Benthos	ST: Moderate Adverse LT: Moderate Adverse In-stream excavation to enlarge the unnamed tributary to Onondaga Creek would disrupt and destroy some existing benthic organisms over a distance estimated to be about 1,000 feet of stream where channel enlargement would occur. Hence, in this portion of the potential work zone, benthic habitat would be temporarily disrupted from this stream's connection with the proposed terrestrial diversion channel, downstream to its junction with Onondaga Creek. Some short-term increased turbidity during construction of the project would temporarily aggravate breathing organs of benthic invertebrates in downstream areas of Onondaga Creek and general vicinity of its mouth with the Lakes. Enlargement of a portion of the unnamed stream to Onondaga Creek would increase the amount of submerged aquatic habitat for future use by benthic organisms. However, installation of the intercepting diversion channel would permanently divert water from flowing through the mud boil area. This means that about 1,600 feet of existing aquatic habitat would no longer be available for future use benthis invertebrates. From the mud boil zone downstream to the unnamed tributaries' junction with Onondaga Creek (a distance of about 1,700 feet) in stream benthic habitat of questionable quality would also be permanently lost due to cut off of the water supply and excavation of a sediment basin. About 1,200 feet of new benthic habitat would be provided by the new diversion channel

Table 10E : Non-Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
· Fisheries	ST: Moderate Adverse LT: Major Beneficial Construction activity would temporarily cause many fish to temporarily avoid the zone of immediate construction activity. Temporary increased turbidity in the unnamed stream as well as in downstream areas of Onondaga Creek during construction could aggravate fish breathing. Long-term loss of approximately 1,600 linear feet of stream above the mud boils, as well as loss of about 1,700 linear feet of questionable (poor quality) habitat immediately below the mud boils would occur. Implementation of this alternative would disrupt about 1,000 linear feet of existing fisheries habitat in that portion of the unnamed stream tributary to Onondaga Creek where the channel would be excavated. However, aquatic habitat would be expanded to some degree by channel enlargement in this same section of stream, which would be available for future utilization as fish habitat. Also, significant reduction or elimination of turbidity induced by silt flows into Onondaga Lake would contribute to fish habitat improvement in this water body. About 1,200 linear feet of new fish habitat would be provided by the new diversion channel.
· Vegetation	ST: Moderate Adverse LT: Moderate Adverse A new channel diversion cut through a terrestrial field would eliminate existing woody and herbaceous vegetation over approximately 2.5 acres of land; it is possible that the sediment basin construction could eliminate about 0.5 more acres of vegetation. Field observation of these areas would be required to confirm vegetation types that would be affected. Additionally, where stream enlargement is planned, riparian woody and herbaceous vegetation would be lost. Some vegetation would likely be replaced by planting.
· Wildlife	ST: Moderate Adverse LT: Moderate Adverse About 2.5 acres of existing terrestrial wildlife habitat would be lost by new channel diversion excavation; also about 0.5 acres of additional wildlife habitat may be lost by sediment basin excavation. Existing riparian vegetation along the unnamed tributary to Onondaga Creek may also be destroyed by stream enlargement.

Table 10E : Non Point Sources, Onondaga Creek (Settling Basin and Diversion) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
· Threatened and Endangered Species	ST: Not Significant LT: Not Significant Similar statement as indicated for the No Action Alternative. Also, if this alternative is selected, the potential project site would be further evaluated for potential impacts by additional field observations and coordination with the NYSDEC and USFWS.
· Wetlands	ST: Not Significant LT: Not Significant A review of USFWS and NYSDEC wetland inventory maps indicated that there are no known fresh water wetlands identified as present in the immediate area of potential project construction. Therefore, no adverse impact on such resources would be anticipated.

Table 10F : Other Measures (By Others) (Generally Assessed)

Evaluation Parameter	Anticipated Impacts and Remarks
HUMAN (MAN-MADE) RESOURCES	
Community and Regional Growth	ST: Minor Adverse LT: Minor Beneficial Project cost is primarily non-Federal. Alternative measures would significantly reduce remaining sewage treatment and/or combined sewer outflow pollution problems to the Lake. Water quality would be expected to gradually continue to improve. However, some lake water quality problems may persist, as some pollution precipitate sediments are recycled back into the water; and landfill leachate and urban run-off continue to drain into the lake. Upper level sediment quality may gradually improve as cleaner sediments cover more polluted sediments. Potential movement and/or mixing of polluted sediments would likely remain high. Improved water quality conditions would facilitate aesthetics and associated desirable upland development plans (i.e., parks, hike/bike trail, restaurant, museums, etc.) and some water associated activities and developments (i.e., boating, marinas, etc.). Continued sediment quality concerns may continue to limit some water associated activities and developments (i.e., swimming, beaches, fisheries, fishing, etc.).
Displacement of People	ST: Minor Adverse LT: Not Significant It is not anticipated that this alternative would result in any displacement of people. It is possible however, that implementation of some structural facilities may require displacement of people and acquisition of property.
Displacement of Farms	ST: Not Significant LT: Not Significant It is not anticipated that this alternative would result in any displacement *of farms or disruption to* any farm activity or district.

Table 10F : Other Measures (By Others) (Generally Assessed) (Cont d)

Evaluation Parameter	Anticipated Impacts and Remarks
Business/Industry Employment/Income	ST: Minor Beneficial LT: Minor Beneficial Alternative implementation may provide business, employment, and income opportunities for project work oriented establishments for up to a several year period. Alternative associated long term environmental quality improvements (primarily water quality) would in-turn facilitate some desirable long-term community and regional growth activities and developments and associated business, employment, and income opportunities associated with aesthetics, parks, boating, marinas and services, restaurants, etc.
Recreation	ST: Not Significant *LT: Minor Beneficial* Alternative associated long term environmental quality improvements (primarily water quality) would in-turn facilitate long term potential for desirable recreational activities and developments associated with aesthetics, parks, boating, marinas and services, etc.
Public Facilities and Services	ST: Moderate Beneficial LT: Moderate Beneficial Project cost is primarily non-Federal. The alternative pertains to modification of municipal sewage treatment plants and combined sewer overflow facilities. Alternative associated long-term environmental quality improvements (primarily water quality and health and safety) would in-turn facilitate desirable long term community and regional (public facilities and services) activities and developments associated with aesthetics, parks, boating, marinas and services, etc. Associated public facilities and services would need to be developed accordingly.

Table 10F Other Measures (By Others) (Generally Assessed) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
Property Values and Tax Revenues	ST: Minor Adverse LT: Minor Beneficial Project cost is primarily non-Federal requiring associated resources. Alternative associated long-term environmental quality improvements (primarily water quality and health and safety) would in-turn facilitate desirable long-term community and regional growth activities and developments associated with aesthetics, parks, boating, marinas and services, etc. Associated property values and tax revenues would be expected to increase accordingly.
Noise and Aesthetics	ST: Minor Adverse LT: Minor Beneficial The alternatives pertain to modification of municipal sewage treatment plants and combined sewer overflow facilities. This may involve construction and operation of construction equipment which would generate some noise and disrupt immediate construction area aesthetics; primarily for the short-term. Generally, improved lake conditions (primarily water quality) would improve the aesthetics of the Lake and vicinity. Alternative associated long-term environmental quality improvements may in-turn facilitate desirable long-term community and regional activities and developments associated with aesthetics, parks, boating, marinas and services, etc. This may involve construction and operation of construction equipment which would generate some noise and disrupt immediate construction area aesthetics temporarily. Developments or redevelopments could alter lake vicinity aesthetics to some degree. No significant adverse long-term impacts would be expected.
Community Cohesion	ST: Minor Adverse LT: Minor Beneficial This alternative pertains primarily to the first two items of a clean-up progression of pollution sources, water quality, and sediment quality, and is considered to be highly supported by government and the public. Some conflicts pertaining to costs, responsibilities, problems, measures, impacts, effectiveness, clean-up needs, expediency, progress, etc. would be expected. Continued progress in clean up of the Lake and environment would likely serve to pull community factions together toward a common goal.

Table 10F Other Measures (By Others) (Generally Assessed) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
CULTURAL RESOURCES	
Cultural Resources	ST: Minor Adverse LT: Minor Beneficial It is expected that Federal, State, and local entities will continue to work to resolve Onondaga Lake water and sediment quality problems and redevelopment plans into the future. Projects, particularly construction projects that could impact cultural resources, will need to be coordinated with cultural resource agencies for clearance and/or possibly mitigation measures. Although construction projects could disrupt cultural resource items, the required studies and/or coordination would facilitate cultural resources awareness and documentation.
NATURAL RESOURCES	
Air Quality	ST: Not Significant LT: Not Significant No significant adverse impact on ambient air quality would be anticipated by implementation of improvements to the sanitary and storm sewer systems, the metro SSTP or by centralized/regionalized collection and treatment facilities. There may be some short-term localized intermittent odor in the immediate vicinity of regional treatment sites during runoff events. Sewage flows to treatment facilities would be transmitted through pipes.
Water Quality	ST: Moderate Beneficial LT: Major Beneficial Elimination of bypasses and further reductions of sewage overflows in the system would help reduce bacterial contamination and provide some reduction of the wet weather loadings of nutrients and biochemical oxygen demand. In the long-run water quality in Onondaga Lake would be improved. Also, refer to statements on this parameter as addressed in the water quality matrix of the Reconnaissance Report. Reference Table 31 in the Reconnaissance Report entitled "Evaluation of Lake Rehabilitation on Onondaga Lake and the Seneca River."
Plankton	ST: Moderate Beneficial LT: Moderate Beneficial Reduction in organics and solids into the Lake due to improvements in transmission and treatment of sewage, would decrease nutrient loadings into this water body. Eventually, such reduction in nutrients would probably be a contributing factor influencing distribution, diversity, population densities and possibly frequency of occurrence of some species of phytoplankton and zooplankton in the lake. Plankton would be less exposed to sewage pollution in this aquatic environment.

Table 10F - Other Measures (By Others) (Generally Assessed) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
· Benthos	ST: Moderate Beneficial LT: Major Beneficial Elimination of by passes, further reduction of sewage overflows, organics and solids into the lake would improve the quality of beuthic habitat over time. Eventually, with improved substrate conditions and water quality, less pollution tolerant macroinvertebrate organisms would likely establish in the benthic environment of the littoral zone where oxygen conditions are likely to be better.
· Fisheries	ST: Moderate Beneficial LT: Major Beneficial Decreased pollution would contribute significantly toward improvement of fish habitat in Onondaga Lake. Water quality improvement and decreased potential for deposition of organics and solids from sewage flows to the lake would upgrade the quality of feeding habitat in the littoral zone where oxygen conditions are likely to be better. If the hypolimnion (deep water zone) of the lake is oxygenated by some acceptable technique, improved oxygenation in this zone, complied with a decrease in organics and solids, as well as improvement in water quality within the lake's water column, would improve and expand the area for use by fish as feeding habitat.
· Vegetation	ST: Moderate Adverse LT: Moderate Beneficial Reduction in nutrient loading, organics and solids into the lake water environment could eventually affect distribution, diversity and/or density of aquatic plant species that may already exist in the lake, or that may establish in the lake in the future. Although there is hard substrate in the area of better sunlight penetration within the littoral zone, the aforementioned nutrient, organic and solids reductions may help decrease filamentous algae establishment and growth, even though water turbidity may be decreased to some degree. However, increased water clarity and better sunlight penetration could also enhance aquatic plant growth of both desirable and undesirable submergent aquatic vegetation. In the long-run, reduction of pollutants into the lake would decrease the potential for accumulation of pollutants by aquatic vegetation.

Table 10F - Other Measures (By Others) (Generally Assessed) (Cont'd)

Evaluation Parameter	Anticipated Impacts and Remarks
· Wildlife	ST: Minor Beneficial LT: Not Significant Improvements in sewage systems and elimination or decrease of pollutant flows into the lake would decrease potential exposure of wildlife to such pollutants. Eventually, improved water quality and substrate would help upgrade the feeding habitat environment in the lake for aquatic birds and furbears (i.e. terns, gulls, waterfowl, muskrats, raccoon).
· Threatened and Endangered Species	ST: Not Significant LT: Not Significant No significant adverse impact on Threatened or Endangered Species would probably be anticipated by implementation of non Federal alternatives. It a non-Federal alternative is selected for implementation, non Federal interests would likely have to coordinate such action with the *USFWS and NYSDEC in this regard.*
· Wetlands	ST: Not Significant LT: Not Significant No significant adverse impact on wetland resources would be anticipated.

SECTION 5 - ENVIRONMENTAL COORDINATION AND COMPLIANCE

INTRODUCTION

5.02 This section briefly summarizes study environmental scoping coordination and compliance with various major environmental legislation and statutes.

ENVIRONMENTAL COORDINATION AND COMPLIANCE

5.02 In order to characterize the resource base of the project area and to facilitate project assessment, information has been obtained from existing literature and coordination with those Federal, State, and local agencies charged with administering fish and wildlife resources, environment and land use plans, and cultural resources. Agencies, interest groups, and publics which have been and/or are geing coordinated with include: the U.S. Department of Commerce, the U.S. Environmental Protection Agency, the Federal Emergency Management Agency, the U.S. Department of the Interior, the U.S. Fish and Wildlife Service, the U.S. Department of Agriculture - Soil Conservation Service, the New York State Clearinghouse, the New York State Department of Environmental Conservation, the New York State Department of Transportation, the New York State Office of Parks, Recreation, and Historic Preservation, the Central New York Regional Planning and Development Board, the Syracuse-Onondaga County Planning Agency, Onondaga County, the Onondaga Lake Advisory Committee, the City of Syracuse, and the towns of Solvay and Geddes. Reference EA Appendix and B and C for correspondence.

5.03 Some specific Environmental Analysis Section coordination is depicted in the following table:

Table 11 - Environmental Coordination

DATE	MEETING
12/12/89	Orientation Meeting for USACOE at USACOE - Buffalo District
01/11/90	Coordination Meeting at NYS DEC - Region 7 Office, Syracuse, NY, Background - Scope of Work
02/14/90	Onondaga Lake Conference U.S. Courthouse, Syracuse, NY
03/21/90	Coordination Meeting at NYS DEC - Region 7 Office, Syracuse, NY (Water Quality - Fish & Wildlife)
05/8-9/90	Field Trip to View the Tributary Outlets and Perimeter of Onondaga Lake.
05/24/90	Review Reference Library at NYSDEC - Region 7 Office, Syracuse, NY
06/12-13/90	Meeting and Field Trip to Syracuse and Onondaga Lake
04/25/90	Scoping Letter to NYSDEC Region 7 for Available Info.
07/26/90	Scoping Letter to USFWS Cortland with SOW for a Reconnaissance Planning Aid Letter
10/02/90	Scoping Letter to NYSDEC - Significant Habitat Unit in Latham, NY
11/13/90	General Scoping Letter to Agencies and Interests

PROJECT COMPLIANCE

5.04 As summarized in Table 3, compliance with pertinent Federal and State environmental statutes is as follows.

5.05 Preservation of Historical Archaeological Data Act of 1974, 16 USC et seq.; National Historic Preservation Act of 1966, as amended, 16 USC 470 et seq.; Executive Order 11593, Protection and Enhancement of the Cultural Environment, 13 May 1971. Project coordination was initiated with the U.S. Department of the Interior (USDOI), and the New York State Office of Parks, Recreation, and Historic Preservation (NYSOPRHP), via letter in November of 1990. The New York State Office of Parks, Recreation, and Historic Preservation indicated in their letter response.

5.06 "Thank you for requesting the comments of the State Historic Preservation Office (SHPO). We have begun to review the project in accordance with Section 106 of the National Historic Preservation Act of 1966 and the relevant implementing regulations."

5.07 "Based upon our review, it is the SHPO's opinion that the Onondaga lake area is known to contain numerous prehistoric and historic archeological sites. We recommend that the reconnaissance survey include a thorough assessment of the project areas history and land use, including both land based and submerged archeological site potential. Actual survey requirements will be greatly influenced by proposed impacts and their locations. Pertinent archeological file source which probably should be consulted are our office, the New York State Museum and the State University of New York at Binghamton, Public Archeology Facility. These contacts, in turn may know of other sources of information."

5.08 "In addition, if any physical or visual impacts are anticipated to buildings over 50 years in age then these buildings and the possible effects warrant consultation."

5.09 Clean Air Act, as amended, 41 USC 7401 et seq. Project coordination was initiated with the U.S. Environmental Protection Agency (USEPA) and the New York State Department of Environmental Conservation (NYSDEC). As indicated in this Environmental Assessment, no significant adverse impacts to air quality would be expected due to project implementation. Some temporary odor may be associated with the use of the CDF. This Environmental Assessment is being coordinated with the USEPA and the NYSDEC in this regard.

5.10 Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972) 33 USC 1251 et seq. Project coordination was initiated with the U.S. Environmental Protection Agency (USEPA) and the New York State Department of Environmental Conservation (NYSDEC).

5.11 If the Onondaga Lake Study is authorized and funded for the additional study phases, a Public Notice and Section 404 (b)(1) Evaluation may need to be prepared for the proposed project and any associated discharges pursuant to the Clean Water Act. Copies of the Public Notice and Section 404(b)(1) Evaluation would then be circulated for public review and comment as an appendix to the combined Study Report/Environmental Impact Statement document. In accordance with Section 401 of the Act, State Water Quality Certification, or a waiver thereof, would be requested in the Section 404(a) Public Notice from the NYSDEC.

5.12 National Environmental Policy Act, 42 USC 470a, et seq. Measures are developed and evaluated in accordance with environmental considerations as set forth by this Act, as promulgated by the Department of the Army's: Principles and Guidelines; ER 200-2-2 Environmental Quality - Policies and Procedures for Implementing NEPA; and COE Section 122 Guidelines. Requirements of the Act are accomplished via the Corps planning process.

5.13 River and Harbor Act, 33 USC 401 et seq. Requirements of this Act are fulfilled via the Corps permit and planning authorities and processes.

5.14 Fish and Wildlife Coordination Act (FWCA) 16 USC 661 et seq. This Act provides a general policy for Conservation of fish and wildlife resources. Its intent is to ensure that Federal and state agencies have an opportunity to comment and make recommendations early in the planning process to prevent loss of valuable fish and wildlife resources. FWCA coordination is normally undertake as part of project documentation, which normally includes an environmental statement.

5.15 In a letter dated 26 July 1990, the Buffalo District initiated coordination with the U.S. Fish and Wildlife Service (USFWS) for preparation of a Planning Aid Letter (PAL), in order to obtain preliminary views on measures being considered by the Corps of Engineers relative to the Onondaga Lake Study. A PAL dated 28 December 1990 was provided by the USFWS containing the Service's preliminary review and comments on the potential project measures. If the Study is authorized and funded to continue into additional study phases, a Fish and Wildlife Coordination Act Report may need to be requested from the USFWS; such a report would also be coordinated by the USFWS with the New York State Department of Environmental Conservation prior to its finalization and submittal to the Corps of Engineers, Buffalo District.

5.16 In addition to meetings held with the USFWS and the New York State Department of Environmental Coordination (NYSDEC) indicated in Table 11 entitled Environmental Coordination in this

assessment, a letter of coordination, dated 25 April 1990, requesting information on natural resources in the general vicinity of Onondaga Lake and its tributaries was sent to the NYSDEC Region 7 office in Cortland, New York. The Region 7 NYSDEC office responded in a letter dated 3 May 1990 by readily offering to share any available information in their files in this regard. In response to the NYSDEC Region 7 letter, a Corps ecologist visit at the Cortland NYSDEC office to review their Onondaga Lake files and to discuss environmental information with biologists on their staff.

5.17 Reference the following paragraphs pertaining to threatened and endangered species, and wetlands also.

5.18 Endangered Species Act, as amended, 16 USC 1531 et seq. Project coordination was initiated with the U.S. Department of the Interior - Fish and Wildlife Service (USDOI-FWS) and the New York State Department of Environmental Conservation (NYSDEC). The U.S. Fish and Wildlife Service indicated in their Planning Aid letter response dated 28 December 1990 that, except for occasional transient species, no Federally listed or proposed for listing endangered or threatened species under their jurisdiction are known to exist in the project impact area. The New York State Department of Environmental Conservation - Wildlife Resource Center indicated in their letter response dated 5 October 1990 that they "reviewed the significant Habitat Unit and the NY Natural Heritage Program files" and "have identified two rare communities which exist on the north shore of Onondaga Lake," namely an "Inland Salt Pond" and an "Inland Salt Marsh." Since the Center could only provide data which have been assembled in their files, continued coordination with the USFWS and the Region 7 NYSDEC office will be maintained if the Onondaga Lake Study is authorized and funded to continue into the next stage of planning, to determine whether or not any on-site surveys are required.

5.19Executive Order 11990, Protection of Wetlands, 24 May 1977. Project coordination was initiated with the U.S. Department of the Interior - Fish and Wildlife Service (USDOI-FWS), the United States Environmental Protection Agency (USEPA), and the New York State Department of Environmental Conservation (NYSDEC).

5.20 The USFWS Planning Aid Letter (PAL) dated 28 December 1990 indicated that the "National Wetlands Inventory maps of the Syracuse West and Camillus Quadrangles indicate a number of wetlands around the periphery of Onondaga Lake." The PAL further stated that the majority of these wetlands consist of the littoral zone of the lake down to the 6-foot contour. "There are several small areas of emergent marsh concentrated along the south end of the Lake and Barge Canal terminal which are, for the most part, perturbed areas with Pliragmites (Pliragmites communis) as the dominant plant. The remaining wetlands are isolated pockets of forested/scrub-shrub wetlands scattered primarily along the western side of the lake. The largest of

these, however, is a forested broadleaved deciduous, seasonally saturated area located at the northeast corner of the lake adjacent to the Onondaga Lake Parkway and Long Branch Park." A review of NYSDEC wetland inventory maps indicates that there are a number of wetlands regulated by the NYSDEC near the shoreline of the lake. These wetlands are identified by the following symbols on the NYSDEC inventory map SYW6 (on the northwest shore near Maple Bay), SYW1 (along the northeast shoreline in the vicinity of Lake Park), SYW10 about midway along the west shoreline, SYW19 at the southwest corner of the lake and SYW12 at the northeast corner of the lake.

5.21 Coastal Zone Management Act, as amended, 16 USC 1451 et seq. Not applicable for this project.

5.22 Wild and Scenic Rivers Act, 16 USC 1271 et seq. In accordance with the National Wild and Scenic Rivers Act, Public Law 90-542, the final lists of rivers identified as meeting the criteria for eligibility dated January 1981 were consulted. Onondaga Lake and tributaries were not listed.

5.23 Federal Water Project Recreation Act, as amended, 16 USC 460-1(12) et seq. This Environmental Assessment is coordinated with the U.S. Department of the Interior, the USFWS, the NYSDEC, and the NYSOPRHP for review in this regard. Both environmental and recreational enhancement measures have been considered during this study.

5.24 Land and Water Conservation Fund Act, 16 USC et seq. This Environmental Assessment is coordinated with the U.S. Department of the Interior for review of conformance with their comprehensive outdoor recreation plan. Both environmental and recreational enhancement measures have been considered during this study.

5.25 Watershed Protection and Flood Prevention Act, 16 USC 1001 et seq. Requirements of the Act are fulfilled via the Corps planning process. None of the considered measures would significantly affect floodplains or potential flooding conditions in the watershed. Project coordination was initiated with the U.S. Department of Agriculture - Soil Conservation Service. One considered measure includes a small stream diversion channel around a sediment producing mud boil area on Onondaga Creek and a sediment settling basin just downstream of the mud boil area to significantly reduce sediment loading to Onondaga Creek and Onondaga Lake.

5.26 Executive Order 11988, Flood Plain Management, 24 May 1977. Project coordination was initiated with the Federal Emergency Management Agency - Regional Office. None of the considered measures would significantly affect floodplains or potential flooding conditions in the watershed.

5.27 Farmland Protection Policy Act (PL 97-98), and Executive Memorandum - Analysis of Impacts on Prime and Unique Farmlands, CEO Memorandum, 30 August 1976. Project coordination was initiated with the U.S. Department of Agriculture - Soil Conservation Service (USDOA-SCS). One considered measure includes a small stream diversion channel around a sediment producing mud-boil area on Onondaga Creek and a sediment settling basin just downstream of the mud-boil area to significantly reduce sediment loading to Onondaga Creek and Onondaga Lake. The settling basin would periodically be cleaned out and sediments disposed of in the near vicinity. If implemented, this measure would occur within a farmland area containing important farmland soils. The scope of the measure indicates that impacts to farmland, soils and activities would be minor. However, if considered further, this measure would need to be coordinated further with the Department of Agriculture - Soil Conservation Service.

5.28 State and local. Study coordination was initiated with State and local agencies. The study appears to be consistent with State and local environmental legislation and local land use plans. To date, coordination indicates that the State and local interests are supportive of the study.

Table 3 - Relationship of Study to Environmental Protection Statutes and Other Environmental Requirements

Federal Statutes	Study
Archeological and Historic Preservation Act, as amended, 16 USC 469, et seq.	Full
National Historic Preservation Act, as amended, 16 USC 470a, et seq.	Full
Clean Air Act, as amended, 42 USC 7401, et seq.	Full
Clean Water Act, as amended (Federal Water Pollution Control Act), 33 USC 1251, et seq.	Full
National Environmental Policy Act, as amended, 42 USC 4321, et seq.	Full
Rivers and Harbors Act, 33 USC 401, et seq.	Full
Fish and Wildlife Coordination Act, as amended, USC 661, et seq.	Full
Endangered Species Act, as amended, 16 USC 1531, et seq.	Full
Coastal Zone Management Act, as amended, 16 USC 1451, et seq.	N/A
Wild and Scenic River Act, as amended, 16 USC 1271, et seq.	N/A
Federal Water Project Recreation Act, as amended, 16 USC 460-1(12), et seq.	Full
Land and Water Conservation Fund Act, as amended, 16 USC 4601-11, et seq.	Full
Watershed Protection and Flood Prevention Act, 16 USC 1001, et seq.	Full
Farmland Protection Policy Act, (7 USC 4201) et seq.	Full
Executive Orders, Memoranda, Etc.	
Protection and Enhancement of the Cultural Environment (EO 11593)	Full
Protection and Wetlands (EO 11990)	Full
Flood Plain Management (EO 11988)	N/A
Analysis of Impacts on Prime and Unique Farmlands (CEQ memorandum, 30 Aug. 76)	Full
New York State Freshwater Wetlands Act (Wetlands >12.4 acres)	Full
Environmental Conservation Law - Article 15 (Protection of Water)	Full
Local Land Use Plans (See Flood Plain Management EO 11988, also)	Full

The compliance categories used in this table were assigned based on the following definitions:

a. Full Compliance - All requirements of the statue, EO, or other policy and related regulations have been met by this stage of the study.

b. Partial Compliance - Some requirements of the statue, EO, or other policy and related regulations, normally met by this stage of planning, remain to be met.

c. Noncompliance - None of the requirements of the statute, or other policy and related regulations have been met.

d. N/A - The statue, EO or other policy and related regulations are not applicable for this study.

VIEWS OF OTHERS

5.29 The following lists interests who responded to the Buffalo District scoping letters and briefly lists points brought out by those interests. The U.S. Fish and Wildlife Service and New York State Department of Environmental Conservation are not listed here but coordination information is integrated into various other sections of the report. The U.S. Fish and Wildlife Service Planning Aid Letter is included as Environmental Assessment Appendix B. Environmental correspondence is included as Environmental Assessment Appendix C.

<u>Town of Geddes</u>

° Look at problems associated with the LCP plant in the village of Solvay and the METRO combined sewer overflow.

<u>Town of Salina</u>

° Consider items in Onondaga Lake Master Development planning.

<u>Village of Solvay</u>

° Look at problems associated with the METRO combined sewer overflow and clean up the west side of the Lake including debris.

<u>Izaak Walton League</u>

° Consider more biological components with considered reclamation measures.

° Review Onondaga Lake Remediation Conference remedial alternatives: contaminated sediments, water column, littoral zone, Ninemile Creek, include Onondaga Creek.

° Consider use of wetlands along west shore of Lake for biological treatment of combined sewer overflow.

<u>Onondaga County - Water Quality Management Agency</u>

° Remediation of Onondaga Lake warrants Federal involvement.

<u>Onondaga County Environmental Management Council</u>

° Remediation of Onondaga Lake warrants Federal involvement.

° Participate in coordinated comprehensive effort.

° Consider 1991 "Diagnostic Study" and possibly other alternatives.

° Prioritize alternatives: In-Lake treatment to dredging sediments.

° Expand Non-Point Sources to include: urban run-off and contaminated ground water problems.

° Consider Other Measures as Federal Measures.

New York State Historic Preservation Office (SHPO)

° The Onondaga Lake area is known to contain numerous prehistoric and historic archeological sites. Appropriate surveys of potentially impacted project areas are required. Also, if any physical or visual impacts are anticipated to buildings over 50 years in age, then these buildings and possible effects warrant consultation.

Onondaga Lake Management Conference

° Acknowledged Buffalo District coordination on measure developments and role with the Onondaga Lake Management Conference.

Onondaga Lake Advisory Committee

° Provided listing of action required and possible measures for:

° Remediation of the mud boils in the Onondaga Creek valley.

° Rehabilitation of Onondaga Creek.

° Rehabilitation of Ninemile Creek.

° Onondaga Lake.

State of New York Department of Transportation

° Consider continued Lake and Onondaga Creek Syracuse Terminal (Lake level and channel maintenance) needs.

° Include Lake and Onondaga Creek Syracuse Terminal channel and upland vicinity in clean-up considerations.

° Consider Lake and Onondaga Creek Syracuse Terminal vicinity redevelopment measures.

U.S. Environmental Protection Agency - Region II

° Continue coordinated effort with the Onondaga Lake Management Conference and USEPA.

° Include a delineation of all potentially impacted wetlands.

° Perform an ecological assessment of the area including inventories of macroinvertebrates, fishery resources, avians, and mammals that utilize the area for nesting and foraging.

5.30 Most of these comments are addressed to some degree in this report or may be pursued in further detail if the study progresses to additional study phases.

ONONDAGA LAKE
Syracuse, Onondaga County
New York

Preliminary
Environmental Assessment

Appendix
References

U.S. Army Corps of Engineers
Buffalo District

REFERENCES

Anderle, R.F. and Carroll, J.R. ed., 1988, _The Atlas of Breeding Birds in New York State_. Carnell University press, Ithaca, New York, 551 p. plus overlay maps.

Aver, M.T., 1989, "Monitoring Fecal Coliform Bacteria in Onondaga Lake and Its Tributaries - 1987." Upstate Freshwater Institute, Syracuse, New York, 110 p.

Aver, M.T.; Storey, M.L.; Effler, S.W.; and Aver, N.A.; ____, "Zooplankton Impacts on Chlorophyll and Transparency in Onondaga Lake, New York, USA." Department of Civil and Environmental Engineering, Michigan Technological University, Houghton, Michigan, 23p.

Aver, M.T. and Niehaus, S.L., 1989, "Fecal Coliform Bacteria Kinetics in Onondaga Lake, New York." Upstate Freshwater Institute, 49 p.

Beilman, Michele D., 1989, "Onondaga Lake. Non-Point Problems Abound."

Bloomfield, J.A., 1979, "Lakes of New York State." Ecology of the Lakes of Western New York. Vol II, 223-365 p.

Bode, R.W.; Novak, M.A.; and Abele, L.E., 1989, "Biological Stream Assessment Tributaries to Onondaga Lake." Stream Biomonitoring Unit, Bureau of Monitoring Assessment, Division of Water, NYS Department of Environmental Conservation, Albany, New York, 29 p.

Brooks, C.M. and Effler, S.W., 1989 "The Distribution of Selected Nitrogen Species in Onondaga Lake, New York." Upstate Freshwater Institute, Syracuse, New York, 124 p.

Cazentre, Don; 1990; "Onondaga Lake. $100,000 Study to Provide Blueprint for Lakeshore." Syracuse Herald American.

CNYRPDB, 1986, "Onondaga Lake and watershed Management Project, Final Report." Central New York Regional Planning and Development Board (CNYRPDB).

CNYRPDB, 1981, "Lake Management Handbook. Central New York Water Quality Management Program, CNYRPDB.

Chiotti, T.L., 1981, "Onondaga Lake Survey Report 1980-1981." New York State Department of Environmental Conservation, 14 p.

Conant, R., 1958, "A Field Guide to Reptiles and Amphibians." Houghton Mifflin Company, Boston, Massachusetts, 366 p.

Cooper, A.L.; Tracy, M.J.; and Neuderfer, G.N., 1974, "A Macroinvertebrate Study of Ninemile Creek." Avon Pollution Investigations, New York State Department of Environmental Conservation, Unpublished Report, 29 p.

Effler, S.W., 1987, "Impact of A Chlor-Alkali Plant on Onondaga Lake and Adjoining Systems." Water, Air, and Soil Pollution, 33 (1987), 85-115 p.

Effler, S.W., 1989, "Onondaga Lake. Can This Lake be Saved?"

Effler, S.W., 1989, "Written Testimony for a Hearing on Onondaga Lake - April 27, 1989, Upstate Freshwater Institute.

Effler, S.W.; Perkins, M.G.; and Brooks, C., 1986, "The Oxygen Resource of the Hypolimnion of Ionically Enriched Onondaga Lake, New York, USA." Water, Air, and Soil Pollution, 29 (1986), 93-108 p.

Effler, S.W.; Hassett, J.P.; Aver, M.T.; and Johnson, N., 1988, "Depletion of Epilimnetic Oxygen and Accumulation of Hydrogen Sulfide Oxygen in the Hypolimnion of Onondaga Lake, New York." Water, Air, and Soil Pollution, 59-74 p.

Effler, S.W., 1988, "Secchi Disc Transparency and Turbidity." Journal of Environmental Engineering, Vol 114, No. 6, 1436-1447 p.

Effler, S.W.; Brooks, C.M.; Aver, M.T.; and Doerr, S.M., 1990, "Free Ammonia and Toxicity Criteria in a Polluted Urban Lake." Upstate Freshwater Institute, Syracuse, New York, 29 p. plus figures.

Flocke, L., 1990, "Cleaning Up the State's Most Polluted Lake." New York State Department of Environmental Conservation Bulletin No. 53, August 1990, 3-6 p.

Heidtke, T.M., 1989, "Onondaga Lake Loading Analysis: Fecal Coliforms." Upstate Freshwater Institute, Syracuse, New York.

Hennigan, Robert D., 1989, "Onondaga Lake. America's Dirtiest Lake."

Jackson, D.F., 1968, "Algae, Man, and the Environment." Syracuse University Press, Syracuse, New York, 554 p.

Lampert, W.; Fleckner, W.; Rai, H.; and Taylor, B.E., 1986, "Phytoplankton Control by Grazing Zooplankton: A Study on the Spring Clear-Water Phase." Limnol. Oceangr. 31:478-490 p.

Lipe, W.C.; Haley, J.J.; and Ripberger, R.R., 1983, "Report of the Onondaga Lake Subcommittee to the Onondaga County Legislature Committee on Public-Works, Onondaga County, New York."

Murphy, C.B., 1973, "Effect of Restricted Use of Phosphate-Based Detergents in Onondaga Lake." Science, 182 and 379-381 p.

Noble, R.L. and Forney, J.L., 1971, "Fish Survey of Onondaga Lake - Summer 1969." Onondaga Lake Study. Environmental Protection Agency, Water Quality Office, Water Pollution Control Research Series 11060 FAE, April 1971, 487 p.

New York State Department of Economic Development, New York State Business Fact Book - 1988, New York State Department of Economic Development.

NYSDEC, 1990, Water Quality Standards and Guidance Values, New York State Department of Environmental Conservation, Division of Water, Albany, New York.

NYSDEC, 1988, "New York State Air Quality Report - ambient Air Monitoring System." New York State Department of Environmental Conservation, Division of Air Resources, Annual, 1988, DAR-89-1, 199 p.

NYSDEC, "Population Projections," September 1985, New York State Water Quality Management Plan, New York State Department of Environmental Conservation, Division of Water.

NYSDEC, "Descriptive Data of Sewage Treatment Systems in New York State," June 1987, New York State Department of Environmental Conservation, Division of Water.

NYS Department of Health, "Inventory - Community Water Systems, New York State," Vol I - Municipal, 1984, New York State Department of Health, Bureau of Public Water Supply Protection.

NYS Office of Parks, Recreation, and Historic Preservation; "People, Resources, Recreation," 1983, New York state Comprehensive Recreation Plan, New York State Office of Parks, Recreation, and Historic Preservation.

Onondaga County, 1971, "Onondaga Lake Study," Water Quality Office, U.S. Environmental Protection Agency, Water Pollution Control Research Series, Report 11060, 460 p.

Onondaga County, 1990, "Onondaga Lake Monitoring Program, 1988." Onondaga County Department of Drainage and Sanitation, 28 p. plus tables and Appendices.

Onondaga County, "Road Map of Onondaga County, New York," Onondaga County Department of Public Works.

Onondaga Lake Advisory Committee, "Questions and Answers about Salmon 2000," Onondaga Lake Advisory Committee and New York State Department of Environmental Conservation, Pamphlet.

Onondaga Lake Advisory Committee, "Salmon 2000," Onondaga Lake Advisory Committee.

Powell, H. Chandler (PhD Candidate), 1990, "Sediment Data from Onondaga Lake (1988," SUNY College of Environmental Science and Forestry, Syracuse, New York.

Ringler, N.H., ____, "Structure and Function of Biological Communities of Onondaga Lake (Preproposal)." Environmental and Forest Biology, SUNY College of Environmental Science and Forestry, Syracuse, New York, 7 p.

Rupp, Laura, 1989, "Onondaga Lake. Paradise Lost ... And Found?"

Sterns and Wheler, 1990, "Onondaga Lake Monitoring Program 1988," Stearns and Wheler Engineers and Scientists, Cazenovia, New York. document prepared for the Onondaga County Department of Drainage and Sanitation, 28 p. plus tables and figures.

SUNY, "New York State Statistical Yearbook 1987-88," The Nelson A. Rockefeller Institute of Government, State University of New York.

Sze, P., 1975, "Possible Effect of Lower Phosphorus Concentrations on the Phytoplankton in Onondaga Lake, New York, USA." Phycologia 14, 197-204 p.

Sze, P., 1980, "Seasonal Succession of Phytoplankton in Onondaga Lake, New York (USA)." Phycologia (1980) Vol 19(1), 54-59 p.

U.S. Department of Agriculture Soil Conservation Service, 1977, "Soil Survey of Onondaga County, New York." U.S. Department of Agriculture, Soil Conservation Service in cooperation with Cornell University Agricultural Experiment Station, 235 p. plus Index and Guide to Mapping Units.

U.S. Department of Commerce, "County and City Data Book - 1988," U.S. Department of Commerce, Bureau of the Census.

U.S. Department of Commerce, "1985 OBER, BEA Regional Projections," U.S. Department of Commerce, Bureau of Economic Analysis.

U.S. Environmental Protection Agency, "USEPA Region V Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments," 1977, USEPA.

U.S. Environmental Protection Agency, "1989, Part 141 - National Primary Drinking Water Regulations, Code of Federal Regulations, Protection of the Environment, 40, Parts 100 to 149," National Archives and Records Administration.

U.S. Geological Survey (Quad Maps)

ONONDAGA LAKE
Syracuse, Onondaga County
New York

Preliminary
Environmental Assessment

Appendix
U.S. Fish and Wildlife Service
Planning Aid Letter

U.S. Army Corps of Engineers
Buffalo District

100 Grange Place
Room 202
Cortland, NY 13045

19 FEB 91 12 41

December 28, 1990

Major David P. Plank
Acting District Commander, Buffalo District
U.S. Army Corps of Engineers
1776 Niagara Street
Buffalo, NY 14207

Attention: Len Bryniarski

Dear Major Plank:

This Planning Aid Letter (PAL) provides our preliminary review and comment on the Onondaga Lake Reconnaissance Study, Onondaga County, New York.

This letter is intended to assist you in subsequent project planning and does not constitute the report of the *Secretary of the Interior on the project* within the meaning of Section 2(b) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. et seq.).

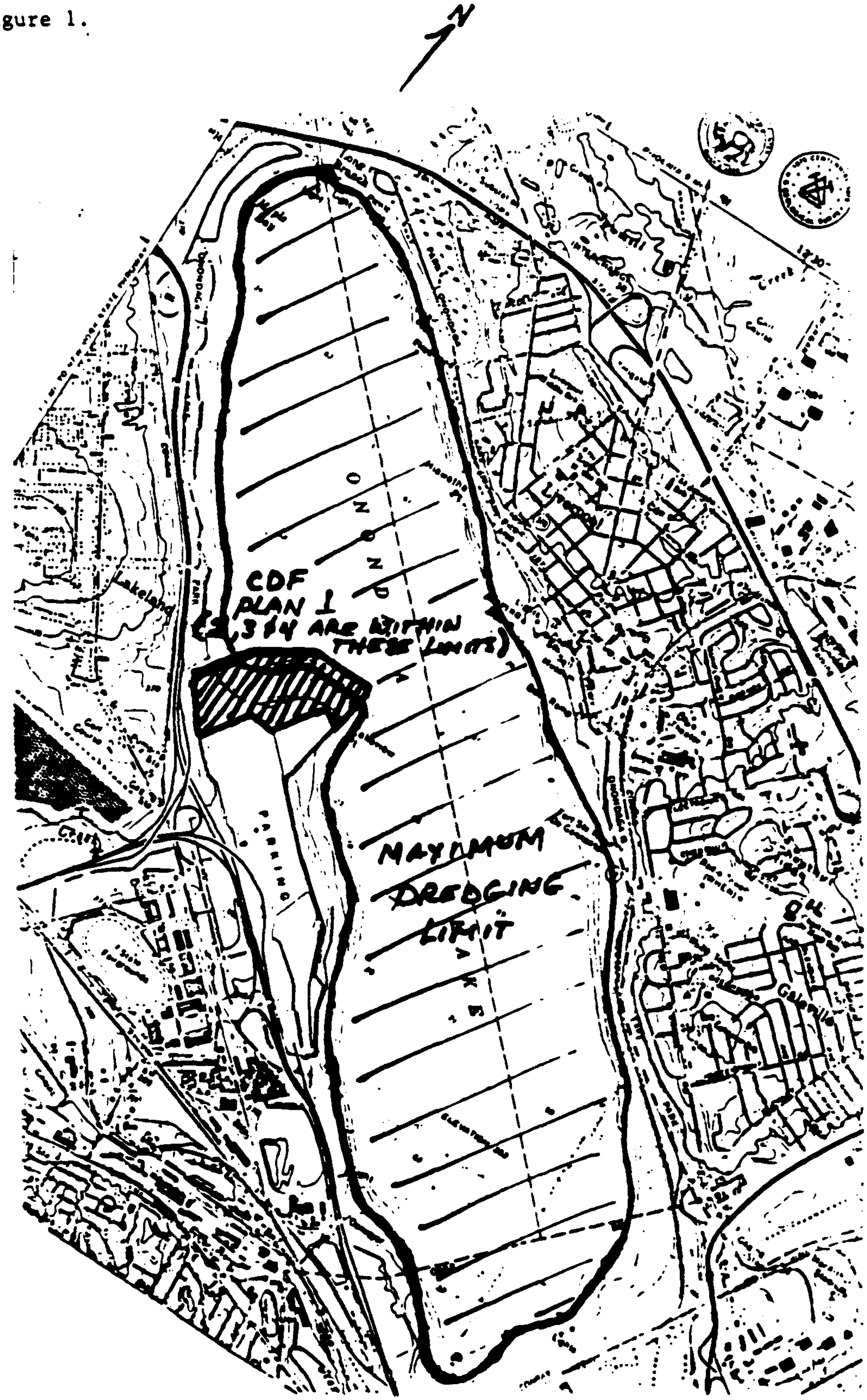
The Buffalo District, Corps of Engineers, is evaluating alternatives for improving the water quality and enhancing the aquatic environment of Onondaga Lake. A number of alternatives are under consideration and are divided into Federal and non-Federal responsibilities. The Federal alternatives are dredging and disposal, solidification, capping, in-lake treatment, and evaluation of a non-point source diversion/sedimentation plan. Non-Federal alternatives involve reducing the pollution load presently discharged into Onondaga Lake and its tributaries from the Metropolitan Syracuse Sewage Treatment Plant (Metro SSTP) and Combined Sewer Overflows located within the Metro SSTP service area.

Federal Alternatives (Figure 1)

1. Dredging

Removal and confinement of an estimated 2,000,000 to 6,500,000 cubic yards of mercury contaminated sediments from an area of Onondaga Lake bottom covering an estimated 1,180 to 2,610 acres. The dredging would take place from shallow near shore areas to the deepest portions of the lake. Dredging depth will range from 0.5 to several feet. It is anticipated that dredging will be performed in a manner and with equipment that will limit re-suspension of sediments. A hydraulic cutterhead dredge is under consideration.

Figure 1.



2. Confined Disposal Facility (CDF)

The dredged material would be placed in a proposed CDF to be constructed along the shoreline of Onondaga Lake. It is anticipated that the CDF would be built along the west shore adjacent to Lakeview Point and the Solvay Process Waste Beds. The CDF would be constructed in water depths ranging from 6 to 22 feet and, depending on the quantity of material and the configuration used, would cover an area ranging from 55 to 92 acres in size and from 34 to 63 feet in height. There are three CDF options under consideration.

A. Plan 1 is a CDF 92 acres in size with dredged material piled to a height of 45 feet.

B. Plan 2 is a CDF 77 acres in size with dredged material piled to a height of 45 feet.

C. Plans 3 & 4 project a CDF 55 acres in size but the height would vary.

3. Solidification

Once in a CDF the contaminated sediments may or may not be further immobilized. The solidification process stabilizes contaminated sediments by binding them into a concrete-like, leach-resistant mass. Binder material may be in the form of cements or pozzolans; proprietary additives may also be added. The potential for chemicals to interfere with the solidification process requires further evaluation of this alternative.

4. Capping

This option involves covering contaminated sediments, in place, with cleaner borrow material. An estimated 1,180 to 2,610 acres of lake bottom would require capping in order to isolate mercury contaminated sediments. For sediments in less than 15 feet of water, a three-layer cap consisting of three feet of sand covered by two feet of gravel and two feet of armor stone (6 to 18 inches in size) would be required. In water depths ranging from 15 to 25 feet contaminated sediments would be covered with a two-layer cap consisting of three feet of sand covered by two feet of gravel. In water depths exceeding 25 feet, the sediments would be covered only with sand capping material. It is anticipated that the sand cap would be between 0.5 foot and 3.0 feet thick. It is assumed that 10 percent of the area to be capped would be covered with the three layer cap, 15 percent would be covered with a two layer cap and the remaining 75 percent would be covered with up to 3.0 feet of sand only. It is anticipated that sand borrow will be available within 10 miles of the project area while the gravel and armor stone will be obtained from quarries in the area.

5. In-Lake Treatment

The two most common treatments are mixing and nutrient inactivation. In the case of Onondaga Lake, mixing will not be considered but will be replaced with hypolimnetic aeration.

A. The first in-lake plan being considered is aeration of the hypolimnion during stratification to maintain dissolved oxygen concentrations near those observed at the beginning of the onset of stratification. This can be achieved by dissolving air or pure oxygen in the bottom waters using aeration devices suspended 1 to 3 feet off the bottom. Because of the large amounts of oxygen needed and the low efficiency of air methods, use of pure oxygen will be investigated. The oxygen will change a reducing environment to an oxidizing environment thereby reducing or eliminating the amounts of phosphorus, metals, hydrogen sulfide, and methane that recycle from the sediments during anoxic conditions.

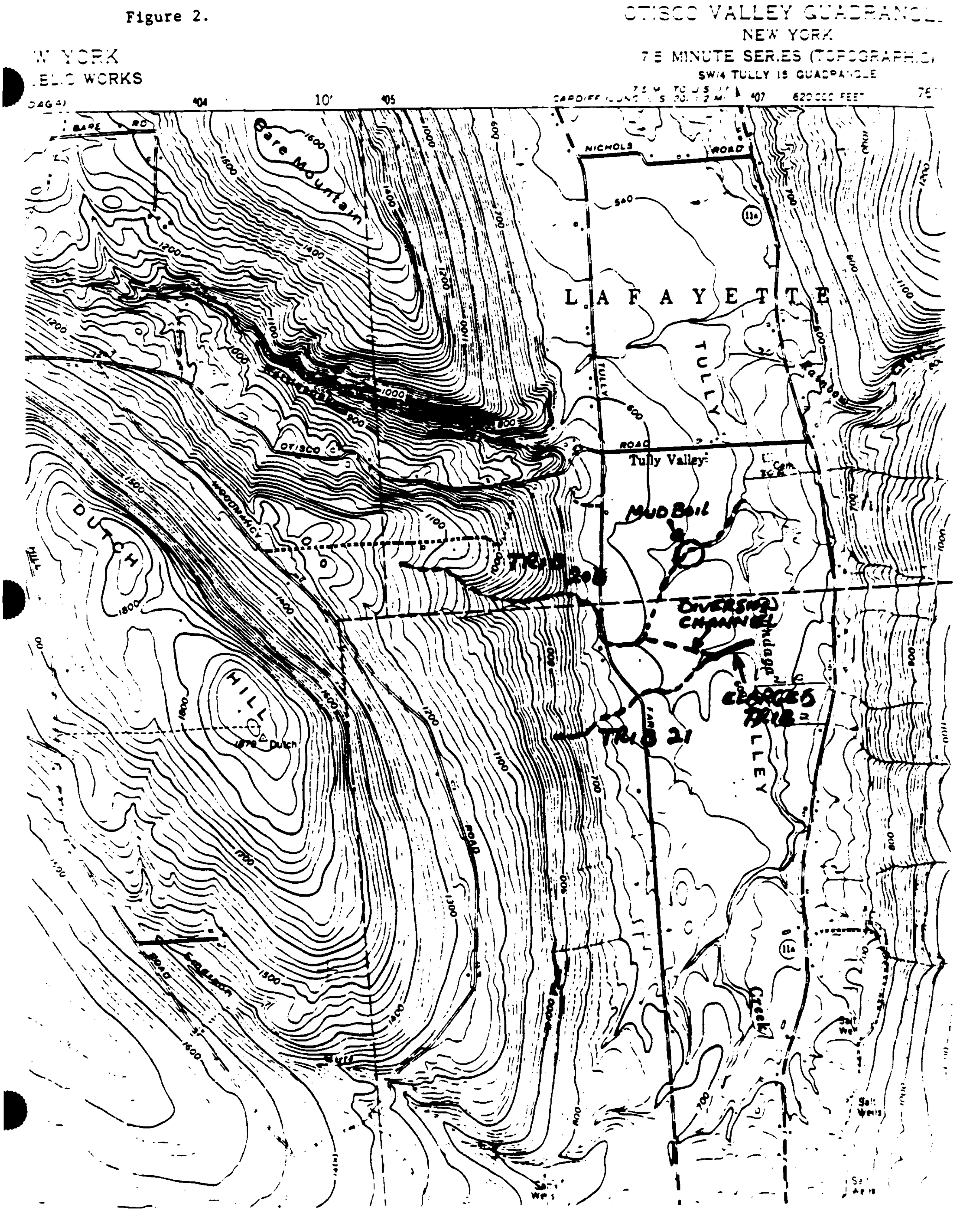
B. The second management plan is the use of alum (Aluminum Potassium Sulfate) to precipitate and remove large amounts of algae, bacteria, phosphorus, and sediment from the water. The immediate noticeable results would be a large reduction in the phosphorus concentration of the water column and a possible decrease in the amount of algae. This would only be a temporary measure and treatment would probably have to be carried out at least twice a year because of the continuing inputs from the Metro SSTP, the tributaries, and bottom recycling if anoxic conditions persist during the summer.

6. Diversion/Sedimentation Plan (Figure 2)

In the late 1800's and early 1900's solution salt mining was carried out along Onondaga Creek in the Tully Valley approximately 15 miles upstream of Onondaga Lake. As a result there has been some subsidence of land in the area. A small unnamed tributary [Waters Index Number (WIN) 20B] drains the hillside area to the west of the valley and south of Otisco Road (State of New York, 1967). A small area in the valley through which this tributary flows has subsided causing a mud deposition area. The tributary is clear before entering this area and muddy after leaving to enter Onondaga Creek. The water in Onondaga Creek above this confluence is clear.

The diversion plan proposes to divert the tributary water before it reaches the mud boil field. The diversion channel would be approximately 1,200 feet long and would be constructed through farm fields to connect with another tributary (WIN 21). From the point of entrance of the diversion channel to tributary 21 to its confluence with Onondaga Creek the tributary channel would be enlarged to handle the additional flow. The cutoff portion of tributary 20B would have local drainage and groundwater flow from the subsidence area. Below the mud boil a settling basin would be constructed to clarify this flow before it reaches Onondaga Creek. Occasionally the settling basin would be cleaned out with the material being deposited nearby. It is expected that this material will be common mud with a high chloride concentration.

Figure 2.


NEW YORK
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 TULLY 15' QUADRANGLE
NICHOLS ROAD
Bare Mountain
L A F A Y E T T E
TULLY
Tully Valley
OTISCO
MUD Boil
DIVERSION CHANNEL
TRIB 21
DUTCH
HILL
Dutch
VALLEY
Creek

Non-Federal Alternatives

1. METRO Syracuse Sewage Treatment Plant (METRO SSTP)

Non-Federal alternatives involving the METRO SSTP include investigation of various methods of phosphorus removal, ammonia removal, and nitrogen removal. Other alternatives include the upgrading of the Ley Creek and Liverpool pump stations. Through the elimination of the bypasses at both pump stations and further reductions of overflows in the system, the result will be to reduce bacterial contamination and provide some reduction of the wet weather loadings of nutrients and biochemical oxygen demand.

2. Combined Sewer Overflow Treatment (CSO) and/or Diversion

This alternative involves separation of the combined sewer system, centralized CSO transmission and treatment, and regional CSO transmission/treatment.

A. Separation of Combined Sewer System

The sewer separation would require the construction of a new sanitary sewer system and the conversion of the combined sewer system into storm sewers. Combined sewer overflows would be eliminated by virtue of eliminating combined sewers.

B. Regionalized CSO Collection and Treatment Facilities

This option includes CSO transmission pipelines that would feed high rate CSO treatment facilities. Swirl concentrators have been found to provide the highest efficiencies for high rate facilities and as such have been selected as the treatment method. The facilities can incorporate either in-line or off-line storage to decrease the design treatment rate. These facilities would concentrate solids and some of the organic matter in the flow and return it, via the underflow sewer to the local interceptor, which then transmits it to the Metro SSTP for treatment (Onondaga Lake or Seneca River discharge). The overflow from the swirl concentrator would be discharged to Onondaga Creek, Harbor Brook, or Ley Creek.

3. Centralized CSO Transmission and Treatment Facilities

The Centralized concept has CSO transmission pipelines leading to three potential treatment alternatives:

1. High rate treatment facilities with underflow to be discharged to either Metro or CSO treatment facilities. The overflow from the facility would be discharged to Onondaga Lake or the Seneca River.

2. In-water contaminant structures known as the flow balance method (FBM). FBM's would provide temporary storage of flow from the centralized CSO transmission pipelines with total pumpback to the METRO STP for treatment.

3. In-Line Tunnel Storage. Storage tunnels would be constructed along the same corridors as the centralized pipelines but would differ in the fact that their diameter would be sized to store all of the flow generated during a design storm. Treatment would be provided at either Metro or a separate CSO treatment facility, with ultimate discharge to either the lake or the Seneca River.

EXISTING CONDITIONS

Onondaga Lake lies entirely within Onondaga County at the northern edge of the City of Syracuse. The lake flows from southeast to northwest and discharges into the Seneca River and eventually into Lake Ontario via the Oswego River, formed by the confluence of the Seneca and Oneida Rivers. The lake is approximately 5 miles long, has a surface area of about 5 square miles (3,200 acres) and drains a basin area of 240 square miles. The lake is divided into two deep pools, each about 69 feet deep. Overall, the average depth of the lake is about 40 feet. The lake is vertically stratified, well-mixed horizontally, and is dimictic: i.e. it undergoes two periods of vertical mixing per year, spring and fall. Tributary streams and the Metro SSTP are the lakes major water sources. There are six major tributaries to the lake: (1) Sawmill Creek enters the lake 0.25 mile east of the outlet, (2) Bloody Brook enters the lake 2.25 miles southeast of the outlet, (3) Ley Creek enters the lake 0.2 mile southeast of a point where the Syracuse city line intersects the east shore of the lake, (4) Onondaga Creek enters the lake at the southeastern end, (5) Harbor Brook enters at the southern most point of the lake and within the city limits, and (6) Ninemile Creek enters the lake along the west shore approximately 2.25 miles from the outlet. There is also an unnamed tributary (WIN 5A) about 1 mile long which enters the west side of the lake about 0.8 mile northwest of the intersection of the Syracuse city line and the west shore of the lake.

The New York State Department of Environmental Conservation (State) has assigned the following water quality classifications to Onondaga Lake and its tributaries.

Onondaga Lake is approximately equally divided between Class "B" waters in the northwestern half and Class "C" waters in the southeastern half. The best usage of Class "B" waters is "*primary contact recreation and any other uses except as a source of water supply for drinking, culinary or food processing purposes.*" Class "C" waters are "*suitable for fishing and all other uses except as a source of water supply for drinking, culinary or food processing purposes and primary contact recreation.*"

Sawmill Creek is Class "B" from the mouth to Euclid Road and Class "D" from Euclid Road to its source. Class "D" waters are "*suitable for secondary contact recreation but due to such natural conditions as intermittency of flow, water conditions are not conducive to propagation of game fishery, or stream bed conditions, the waters will not support the propagation of fish.*"

Bloody Brook is Class "B" from the mouth upstream for approximately 0.4 mile and Class "D" from this point to its source.

Ley Creek is Class "D" from the mouth upstream for approximately 1 mile to the Ley Creek Sewage Treatment Plant outfall and Class "B" from the outfall to the confluence of the south branch, approximately 3 miles. Beartrap Creek which enters Ley Creek approximately 1.1 miles from the mouth is Class "C" with a (T) standard meaning it is a designated trout water.

Onondaga Creek is Class "D" from the mouth to Temple Street in Syracuse, Class "B" from Temple Street to tributary WIN 5B, and Class "C" from tributary 5B to its source with a (T) designation from the confluence with Commissary Creek to its source.

Harbor Brook is Class "D" from the mouth to the upper end of the underground section at Gifford Street, Class "B" from Gifford Street to the Syracuse city line and Class "C(T)" from the City line to its source.

Ninemile Creek is Class "D" from the mouth to Amboy approximately 4 miles upstream.

The unnamed tributary (5A) to Onondaga Lake is Class "D" for its entire length and tributaries 20B and 21 to Onondaga Creek are both Class "D" throughout.

Historically, Onondaga Lake and its tributaries have suffered from the operation of now abandoned chlor-alkali and salt mining industries. Impacts associated with these industries include ionic enrichment, altered temperature stratification regimes, and alterations in the chemistry of lake sediments.

Some aspects of the substrate character of the lake have been examined in the broad sense but detailed information on specific zones in the lake is lacking. It is known that algal-carbonate concretions, or oncolites, are the dominant substrate in much of the littoral zone. There is extensive deposition of a calcium carbonate layer over the entire lake bottom, and a calcium carbonate delta at the mouth of Ninemile Creek. It is also known that almost the entire lake bed is contaminated with mercury at levels ranging from 1.0 part per million (ppm) to in excess of 10 ppm.

The substrates in the lower reaches of both Onondaga Creek and Ninemile Creek are heavily impacted by loads of dissolved and suspended solids being carried into the lake. Ninemile Creek, in particular, carries cations, carbonate, ammonia, and mercury derived from groundwater sources in the waste bed area. Onondaga Creek carries mud with a high chloride content from former salt mining areas in the upper reaches of the Tully Valley.

Information on benthic invertebrates in the Onondaga Lake system is very sparse and information on aquatic vegetation is virtually non-existent. The few invertebrate studies that have been done suggest that diversity is reduced in the lake and the lower reaches of the tributaries. However, analysis of stomach contents from smallmouth bass and several other species indicates a greater diversity than has been evident from examination of littoral samples (Onondaga Lake Habitat Group, 1990).

Casual observation indicates that substantial aquatic vegetation exists along the northeast shore, but is relatively sparsely distributed throughout the remainder of the lake.

The most recent fishery investigation, several months of trap-netting in 1989, produced 30 species. The two most abundant species, by far, were white perch (*Morone americana*) and gizzard shad (*Dorosoma cepedianum*) constituting nearly 77 percent of the total catch with their numbers almost equally divided. The next most abundant species were bluegill (*Lepomis machrochirus*) 12 percent, and pumpkinseed (*Lepomis gibbosus*) 4 percent. The remaining 26 species made up only 7 percent of the total catch (Morgan and Ringler, 1990, Unpublished Data). Game species normally associated with a productive lake of this type such as the yellow perch (*Perca flavescens*), walleye (*Stizostedion vitreum vitreum*), smallmouth bass (*Micropterus dolomieui*), and largemouth bass (*Micropterus salmoides*) were all found in low numbers (less than one percent of the catch in most cases). These fish were all taken near the outlet and the very pronounced skew toward two, and at the most, four species strongly suggests that this species distribution does not represent a resident profile but instead reflects a jumble of species that move in and out of the lake via the Seneca River. Probably only a very few of these species represent populations that carry out their entire life cycle in the lake.

Historically indigenous species like the ciscoes (*Coregonus spp.*) and Atlantic salmon (*Salmo salar*) are absent from the lake and other indigenous species such as the bowfin (*Amia calvia*) and the northern pike (*Esox lucius*) are rare.

Some of the tributaries to Onondaga Creek in the vicinity of the proposed diversion channel provide excellent spawning and nursery habitat for local populations of brown trout (*Salmo trutta*) as well as supporting a good forage base of various minnows and suckers. However, there are no available fishery data for tributaries 20B and 21.

Waterfowl use of the lake is low but steady. Species that have been observed include Mallard (*Anas platyrhynchos*), Black Duck (*Anas rubripes*), Blue-winged Teal (*Anas discors*), Green-winged Teal (*Anas carolinensis*), and some Scaup (*Aythya ssp.*). An occasional Redhead (*Aythya americana*) is sighted. Over the last few years the flyway pattern appears to have shifted away from the Syracuse metropolitan area. Waterfowl are moving by to the east and west of the city but are not coming over the Syracuse area as much (Ward Dukelow, State; personal communication). There is some, very sparse, summer reproduction by mallards in the phragmites stands along the southwestern shore of the lake and there are pockets of breeding habitat in the remnants of the old Erie Canal adjacent to the lake.

Other avian resources that may be observed in the project area include numerous species of songbirds, raptors such as the Red-tailed Hawk (*Buteo jamaicensis*), and aquatic species such as the Great Blue Heron (*Ardea herodias*) and the Belted Kingfisher (*Megaceryle alcyon alcyon*). The Rock Dove, or domestic Pigeon (*Columba livia*) and the American Crow (*Corvus brachyrhynchos*), a scavenger, are common.

Mammals that may be observed in the project area include the Eastern gray squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), Eastern cottontail rabbit (*Sylvilagus floridanus*), woodchuck (*Marmota monax*), striped skunk (*Mephitis mephitis*), and opossum (*Didelphis marsupialis*). An occasional white-tailed deer (*Odocoileus virginianus*) may be seen in the less populated open meadow and wooded areas around the northwest end of the lake.

National Wetlands Inventory (NWI) maps of the Syracuse West and Camillus Quadrangles indicate a number of wetlands around the periphery of Onondaga Lake (Figure 1). The majority, however, consist of the littoral zone of the lake down to the 6 foot contour. There are several small areas of emergent marsh concentrated along the south end of the lake and the Barge Canal Terminal which are, for the most part, perturbed areas with phragmites (*Phragmites communis*) as the dominant plant. Phragmites is characteristic of marginal, somewhat saline, wetland areas. The remaining wetlands are isolated pockets of forested/schrub-scrub wetlands scattered primarily along the western side of the lake. The largest of these, however, is a forested broad-leaved deciduous, seasonally saturated area located at the northeast corner of the lake adjacent to the Onondaga Lake Parkway and Long Branch Park. Sawmill Creek enters the lake through this area.

Except for occasional transient individuals, no Federally listed or proposed endangered or threatened species under our jurisdiction are known to exist in the project impact area. Therefore, no Biological Assessment or further Section 7 consultation under the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.) is required with the Fish and Wildlife Service. Should project plans change, or if additional information on listed or proposed species becomes available, this determination may be reconsidered.

Onondaga Lake and the lower reaches of its major tributaries have been heavily impacted by urban and industrial development. The lake bed is, for the most part, heavily contaminated and the shallow shoreline zone has been drastically altered by dredging, deposition of chlor-alkali industry waste beds, and deposition of calcium carbonate and algal carbonate accretions, especially along the west and southwest shoreline. Portions of the upper reach of Onondaga Creek, and ultimately the lake, are subject to heavy sediment and chloride loading due to groundwater phenomena associated with historic salt mining practices.

In accordance with U.S. Fish and Wildlife Service (Service) Mitigation Policy (See Appendix) the northern pike and the brown trout are selected as evaluation species for the project areas. The Service designates the habitat in Onondaga Lake and the first mile of the major tributaries as Resource Category 4 for the northern pike under the Service Mitigation Policy. The associated mitigation goal is to minimize loss of habitat value. The Service designates the habitat in tributaries 20B and 21 as Resource Category 3 for brown trout under the Service Mitigation Policy. The associated mitigation goal is no net loss of habitat value while minimizing loss of in-kind habitat.

IMPACT ANALYSIS

General Comments:

All of the proposed Federal measures, except for In-Lake Treatment, are primarily aimed at removing or isolating the mercury-contaminated lake sediments. However, since there continues to be ongoing contaminant inputs to the system, additional sampling, analyses, and modeling of the sources and cycling dynamics of the mercury is needed before implementing measures that address the existing mercury load. Assuming that current contaminant input problems will be resolved, these are the Service comments regarding the proposed Federal measures.

Specific Comments:

1. Dredging

The chief impact associated with the removal of up to 6 million plus cubic yards of mercury contaminated sediments is finding the appropriate site and means for disposing of this material. Whether it is upland or in-lake disposal, a significant amount of area is required. On the one hand terrestrial habitat will be eliminated and on the other benthic/littoral habitat will be eliminated. When the dredged material is polluted, as Onondaga Lake sediments will be, provisions have to be made for insuring that the material does not leak contaminants to surrounding upland or waterward areas. The accessibility of Onondaga Lake to the Barge Canal system suggests the feasibility of using existing Department of Transportation (DOT) approved disposal areas should be explored, as opposed to creating a new disposal area in Onondaga Lake itself.

2. Confined Disposal Facility (CDF)

A CDF would reduce the lake's approximately 3,000 acre surface area by up to 3 percent and remove from 55 to 92 acres of potentially productive benthic habitat, primarily in the littoral zone. There is also potential for contaminants to leach back into the surrounding open water through the containment dikes. Measures to prevent leakage that should be evaluated include a clay core or a sheet pile barrier in the containment walls.

Depending on the final elevation and contouring of the interior there is also a tendency for wetlands to develop inside CDF's. If the contents are heavily contaminated this can pose a threat to various animal species attracted to the habitat. Sealing, and then capping the contents with clean fill material could provide protection for fish and wildlife resources.

3. Solidification

If a CDF was a selected alternative the further immobilization of contaminants by binding them into an inert leach-resistant state would be of benefit. Since the solidified material would already be inside the CDF no additional

disposal area would be required. The technology does have drawbacks however, and more information is necessary before considering this as a measure to be tied to disposal of contaminated sediments.

4. Capping

Capping would cover as much as 2,610 acres of existing lake bottom having elevated mercury concentrations ranging from 1 ppm to in excess of 10 ppm. Assuming the existing substrate is relatively sterile in terms of benthic invertebrates and aquatic macrophytes the major effect of this proposal would be to reduce water depth to some extent throughout a large part of the lake. This may elevate some areas into the zone of light penetration while clean, heterogeneous bottom materials, in the absence of additional contaminant input, may accelerate benthic recolonization and the re-establishment of aquatic macrophytes. Clean substrate in the shallower areas may also encourage spawning activity by various species of fish and provide suitable nursery and grazing habitat for juvenile fishes.

5. In-Lake Treatment

There is insufficient available information on these techniques to assess potential impacts. Oxygen and alum are not themselves toxic, but lacking thorough knowledge of possible chemical interactions beyond those intended this alternative should be evaluated further.

6. Diversion/Sedimentation Plan

Since detailed construction plans are not available the areal extent of terrestrial impacts associated with construction of the proposed diversion channel are not quantifiable. There would be conversion of upland habitat to seasonal aquatic habitat but overall the habitat value within the newly constructed channel would be reduced, at least initially.

There will be some impact, probably temporary, on aquatic habitat in that portion of Tributary 21 that is to be enlarged and benthic/spawning habitat could be affected in the respective tributaries by construction-related alterations of their hydrology.

7. Non-Federal Alternatives

These options are described only in broad outline so it is difficult to assess potential impacts. Some of the proposals involve modifications to existing facilities and methodologies and would have little, if any, impact. Those options that require new construction are not described in sufficient detail to quantify potential impacts.

ENVIRONMENTAL ENHANCEMENT

Much of the habitat value of Onondaga Lake and portions of the associated tributaries has been, and continues to be, severely impacted. Long-term, the rectification of the current situation involves permanent improvement in water quality through reduction, and ultimately, elimination of the contaminant load

now entering the system and presently in the system. Although beyond the scope of this project the initial priority should be the elimination or isolation of the chlor-alkali industry inputs to the system. This would, in turn, help to reduce the alkalinity of the lake and interdict much of the mercury contamination entering the system.

However, assuming that long-term, system-wide water quality improvement will occur, there are enhancement measures associated with the present project that should be evaluated.

1. Determine the feasibility of a permanent, regulated water connection between the lake and the large wetland area at the northeast corner of the lake. This could provide access to seasonally flooded spawning habitat for species such as the northern pike.

2. Determine the feasibility of enhancing seasonal flooding along the south side of Ley Creek up to the Conrail embankment and Wolf Street to provide spawning habitat for northern pike.

3. Identify other wetland areas, or potential wetland areas, around Onondaga Lake where permanent water connections to the lake can be established and maintained to promote fish and waterfowl use.

4. Determine the feasibility of establishing, or re-establishing, emergent wetlands along the southern shore of the lake.

Based on the available resource information and the nature of the present project proposal, we anticipate the need for biological studies. Such studies, as we identify, will be coordinated with the Corps of Engineers at the next planning stage.

Thank you for the opportunity to comment on this Reconnaissance Study. Please keep us informed of any changes in project plans. If you have any questions concerning this report please contact Thomas McCartney at (607) 753-9334.

Sincerely,

Carl W Schwartz

ACTING FOR
Leonard P. Corin
Field Supervisor

cc:
NYSDEC, Albany; Syracuse; Cortland
EPA, Water Mgmt. Div., NY, NY
EPA, Chief, Marine & Wetlands Protection Br., NY, NY

LITERATURE CITED

1. Onondaga Lake Habitat Group (1990)
   Recommendations and Conclusions of the Onondaga Lake Habitat Group, Report of Conference at the Sagamore Inn, February 6-9, 1990.

2. Morgan, C.A., and N.H. Ringler (1990)
   Preliminary Analysis of Fish Community Data on Onondaga Lake, NY. (Unpublished Tables and Figures Cited in the Report of the Onondaga Lake Habitat Group).

3. State of New York (1967)
   Official Compilation, Codes, Rules, and Regulations of the State of New York. Title 6 Conservation (E), Part 895 of Article 14, Onondaga Lake Drainage Basin.

APPENDIX A: Fish and Wildlife Service Mitigation Policy Synopsis

Under the Fish and Wildlife Coordination Act and the National Environmental Policy Act, the Fish and Wildlife Service (Service) has responsibilities to ensure that project-related losses to fish and wildlife resources are identified and mitigated. As part of our participation in project planning, a mitigation plan should be developed in accordance with the Service Mitigation Policy (FR Vol. 46, No. 15, January 23, 1981) [and in consultation with the Environmental Protection Agency, and the New York State Department of Environmental Conservation]. The plan would provide guidance for evaluating and mitigating impacts of the proposed project to fish and wildlife.

A mitigation plan is developed by first selecting fish and wildlife habitats from among the full range of habitats occurring within the area to be impacted by both direct as well as indirect impacts. These are chosen either because they represent resources which are most characteristic of the area or because the Service has mandated responsibilities for them. By narrowing the scope in this way, the analysis can focus on areas where significant changes are most likely to occur and not be unduly burdened by inclusion of areas with low wildlife value.

After identifying important habitats, evaluation species, which function as indicators of habitat quality and quantity, are chosen. Selection of evaluation species has an important role in determining the extent and type of mitigation achieved. A combination of two sets of criteria is typically used to choose species for this purpose. The first is to pick species with high public interest, subsistence, or economic values while the second is to select species which utilize habitats having significant ecological values.

Fish and wildlife habitats are then assigned to one of the four Resource Categories delineated in the Mitigation Policy (Table A-1). Designation of habitat into Resource Categories ensures that the level of mitigation recommended is consistent with the value of that habitat and its relative abundance on an ecoregion or national basis.

The determination of the relative scarcity or abundance of evaluation species' habitat from the national perspective is based upon: 1) the historical range and habitat quality, and 2) the current status of that habitat. A significant reduction in either the extent or quality of habitat for an evaluation species indicates that it is scarce or becoming scarce, while maintenance of historical quantity and quality is the basis for considering it abundant.

For all Resource Category 1 habitat, the Service will recommend that all losses of existing habitat be prevented, as these one-of-a-kind areas cannot be replaced. Insignificant changes that do not result in adverse impacts on habitat value may be acceptable provided they will have no significant cumulative impact.

Table A-1. Resources Categories and Mitigation Planning Goals.[1]

Resource Category	Designation Criteria	Mitigation Planning Goal
1	Habitat to be impacted is of high value for evaluation species and is unique and irreplaceable on a national basis or in the ecoregion section.	No loss of existing habitat value.
2	Habitat to be impacted is of high value for evaluation species and is relatively scarce or becoming scarce on a national basis or in the ecoregion section.	No net loss of in-kind habitat value.
3	Habitat to be impacted is of high to medium value for evaluation species and is relatively abundant on a national basis.	No net loss of habitat value while minimizing loss of in-kind habitat value.
4	Habitat to be impacted is of medium to low value for evaluation species.	Minimize loss of habitat value.

[1] Service Mitigation Policy (FR Vol. 46, No. 15, 23 January 1981).

Specific ways to achieve the mitigation goals for Resource Category 2 when loss of habitat value is unavoidable include: 1) physical modification of replacement habitat to convert it to the same type which was lost; 2) restoration or rehabilitation of previously altered habitat; 3) increased management of similar replacement habitat so that the in-kind value of lost habitat is replaced; or 4) a combination of these measures. By replacing habitat value losses with similar habitat values, populations of species associated with that habitat may remain relatively stable in the area over time.

The mitigation goal of in-kind replacement of lost habitat, however, cannot always be achieved. When opposition to a project on that basis alone is not warranted, deviation from this goal may be appropriate. Two such instances occur when either different habitats and species available for replacement are determined to be of greater value than those lost, or when in-kind replacement is not physically or biologically attainable in the ecoregion. In either case, replacement involving different habitat kinds may be recommended, provided that the total value of the lost habitat is compensated.

For Resource Category 3, in-kind replacement of lost habitat is preferred though not always possible. Substituting different habitats, or increasing management of different habitats so that the value of the lost habitat is replaced, may be ways of achieving the planning goal of no net loss of habitat value.

For Resource Category 4, the Service will recommend ways to avoid or minimize losses. If losses are likely to occur, then the Service will recommend ways to immediately rectify them or to reduce or eliminate them over time. If losses remain likely to occur, then the Service may make a recommendation for compensation, depending on the significance of the potential loss. However, because these areas possess relatively low habitat values, they will likely exhibit the greatest potential for significant habitat value improvements. Service personnel will fully investigate these areas' potential for improvement, since they could be used to mitigate Resource Category 2 and 3 losses.

ONONDAGA LAKE
Syracuse, Onondaga County
New York

Preliminary
Environmental Assessment

Appendix
Environmental Correspondence

U.S. Army Corps of Engineers
Buffalo District

APR 25 1990

Environmental Analysis Section

SUBJECT: Onondaga Lake Reconnaissance Study

Mr. Brad Griffin
Regional Supervisor
New York State Department of
Environmental Conservation
P.O. Box 5170, Fisher Avenue
Cortland, New York 13045

25 APR 90 MAILROOM

Dear Mr. Griffin:

The Buffalo District Corps of Engineers is currently conducting a reconnaissance study of Onondaga Lake in Syracuse, New York. The purpose of the reconnaissance study is to determine what improvements in the interest of water quality and environmental enhancement are advisable for Onondaga Lake. Federal interest will be determined for further study beyond the reconnaissance phase.

As part of the assessment for a reconnaissance report, my environmental staff is conducting a literature search of available information, for use in describing existing environmental conditions in the vicinity of Onondaga Lake, as well as its tributaries which include: Ley Creek, Onondaga Creek, Harbor Brook, Nine Mile Creek, and the Barge Canal.

I would appreciate receiving any information your office can provide, that would be of assistance to my staff in describing existing environmental conditions, with respect to fisheries, benthos, plankton, wildlife, aquatic vegetation and wetlands associated with the lake and aforementioned tributaries. Also, if there are any unique environmental features, concerns, or plans that I should be aware of in the aforementioned study locale, please let me know.

Since the reconnaissance study is being done within a very limited time frame, I would appreciate receiving the requested information by May 11, 1990. I will continue to coordinate with your office throughout the reconnaissance phase of the Onondaga Lake study. Upon completion of the reconnaissance report, a copy of the report will be provided to your office for review and comment.

MISC-1 4173/A8
35 F-4/19/90
C&F-4/20/90
R&F-4/24/90

Environmental Analysis Section
SUBJECT: Onondaga Lake Reconnaissance Study

My point of contact pertaining to this matter is Mr. Leonard Bryniarski of my Environmental Section, who can be contacted calling (716)879-4173 or by writing to his attention at the above address.

Sincerely,

SIGNED
Hugh F. Boyd III
Colonel, U.S. Army
Commanding

New York State Department of Environmental Conservation
Region 7
Natural Resources Office
P. O. Box 5170, Fisher Avenue
Cortland, New York 13045-5170
(607) 753-3095

MAILROOM NCBIM-S

7 MAY 90 10 23

Thomas C. Jorling
Commissioner

May 3, 1990

Colonel Hugh F. Boyd III
Attn: Leonard Bryniarski
Department of the Army
Corps of Engineers
1776 Niagara Street
Buffalo, NY 14207-3199

Re: Onondaga Lake Reconnaissance Study

Dear Col. Boyd/Mr. Bryniarski:

Your staff is welcome to review our files on Onondaga Lake and its tributaries. That data includes sampling performed on those waters over several decades by staff from our Regional Fisheries Unit.

Len Bryniarski can schedule visits here to see what may be helpful, and we will try to make some opportunity for him to summarize or copy from our records.

The Regional Fisheries Manager and his staff will also share their anecdotal recollections and respond to any questions which Len may have on your behalf.

Please advise me of any other needs for assistance or information in which I may help you.

Sincerely,

Brad

Bradley L. Griffin
Regional Supervisor

BLG:klw

cc: C. Creech (w/att.)
W. Krichbaum (w/att.)

JUL 26 1990

Environmental Analysis Section

SUBJECT: Onondaga Lake

Mr. Leonard Corin
Field Supervisor
Ecological Services Office
Fish and Wildlife Service
100 Grange Place, Room 202
Cortland, New York 13045

Dear Mr. Corin:

The U.S. Army Corps of Engineers, Buffalo District is currently initiating a Reconnaissance Study of Onondaga Lake, located northwest of Syracuse, in Onondaga County, New York. The purpose of the study is to determine what improvements in the interest of water quality and environmental enhancement may be feasible for the Lake. This study is being conducted under a Resolution by the Committee on the Environment and Public Works of the United States Senate dated June 1989. Funding for the Reconnaissance Study was appropriated by a Report for HR 2696 Energy and Water Development Appropriations Act, 1990 (Public Law 101-101, approved September 29, 1989).

Implementation of the National Environmental Policy Act of 1969 (NEPA), as amended, requires that Federal agencies initiate "an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to the proposed action." As a part of this early scoping process, I wish to invite your participation in this study.

In order to obtain preliminary views of the USFWS relative to significant fish and wildlife resources, assessment of Corps alternatives and identification of improvements for environmental enhancement (in Onondaga Lake and its associated tributaries), I

Environmental Analysis Section
SUBJECT: Onondaga Lake

am requesting a Planning Aid Letter (PAL) from the USFWS. Enclosed is a Scope of Work (SOW) to be used in preparation of the PAL. Please provide me with the USFWS written cost estimate on the SOW by August 10, 1990, so that I can initiate timely preparation of DD Form 2544 to obligate funding for this work.

My point of contact pertaining to this matter is Mr. Leonard Bryniarski of my Environmental Analysis Section, who can be contacted by calling 716-879-4173 or by writing to his attention at the above address.

Sincerely,

HUGH F. BOYD III
COLONEL U.S. ARMY
COMMANDING

Hugh F. Boyd III
Colonel, U.S. Army
Commanding

CONVERSATION RECORD

TIME: 11:30
DATE: 9-11-90

TYPE: ☐ VISIT ☐ CONFERENCE ☐ TELEPHONE ☐ INCOMING ☒ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU: Clifford Creech, Region 7 (Regional Fisheries Mgr.)

ORGANIZATION (Office, dept., bureau, etc.): NYSDEC

TELEPHONE NO: 607/753-3095

SUBJECT: Onondaga Lake Fisheries

SUMMARY

Onondaga Lake was closed to fishing in the early 1970's and reopened in May 1986 with a strong health advisory not to consume any fish caught.

No current significant use of Sawmill Creek, Bloody Brook and Ley Creek by Onondaga Lake fishes. Gizzard shad and Carp were observed in Ley Creek.

Trout are found in Ninemile Creek down to its mouth and in general is considered to be an excellent trout stream.

ACTION REQUIRED

File

NAME OF PERSON DOCUMENTING CONVERSATION: Len Brynciarski

SIGNATURE:

DATE: 9-11-90

ACTION TAKEN

SIGNATURE:

TITLE:

DATE:

6

CONVERSATION RECORD

TIME 3:30 | DATE 9-25-90

TYPE

☐ VISIT ☐ CONFERENCE ☐ TELEPHONE

☐ INCOMING

☒ OUTGOING

Location of Visit/Conference:

ROUTING	
NAME/SYMBOL	INT

NAME OF PERSON(S) CONTACTED OR IN CONTACT WITH YOU: John Proud

ORGANIZATION (Office, dept., bureau, etc.): NYSDEC Cortland, NY

TELEPHONE NO: 607/753-3095

SUBJECT: Wildlife - vicinity of Onondaga Lake

SUMMARY

No information available. "Atlas of Breeding Birds in NYS" would be of help. Also suggested telephoning Larry Brown @ Significant Habitats Unit (NYSDEC) in Latham, N.Y.

J. Proud indicated that "saving or enhancing wetlands around Onondaga Lake" should be an important concern.

ACTION REQUIRED

File

NAME OF PERSON DOCUMENTING CONVERSATION: Len Bryniarski

SIGNATURE:

DATE: 9-25-90

ACTION TAKEN

SIGNATURE

TITLE

DATE

7

MISC-2
245
245a

Environmental Analysis Section

SUBJECT: Threatened and Endangered Species - Onondaga Lake Study

Mr. Larry Brown
Significant Habitat Unit
Wildlife Resources Center
New York State Department of
Environmental Conservation
700 Troy-Schenectady Road
Latham, New York 12110

2 OCT 90 14 47

OCT 2 1990

Dear Mr. Brown:

As discussed in your recent telephone conversation with Mr. Leonard Bryniarski of my Buffalo District staff on September 26, 1990, I am requesting information relative to any known threatened or endangered species and significant habitats in the general vicinity of Onondaga Lake, located in Onondaga County, New York. The vicinity of interest would include the immediate area of the lake, as well as within an approximate radius of 1 mile from the lake. The requested information would be helpful in considering planning alternatives relative to a study of Onondaga lake that is presently being conducted by my office.

Please provide two separate lists (or narratives) of any such available information. One list would be used by my office staff that would be more specific in content to assist them in their planning effort, and; another list (or narrative) that is more general in content that could be included in a public document reconnaissance report. I request that the aforementioned information be provided to my office by October 10, 1990.

If you require additional information on this matter, please contact Mr. Leonard Bryniarski, of my Environmental Analysis Section, who can be contacted by calling (716)879-4173 or writing to his attention at the above address.

Sincerely,

SIGNED

George B. Brooks, P.E.
Chief, Engineering & Planning Division

Environmental Analysis Section NOV 13 1990

SUBJECT: Onondaga Lake, Onondaga County, New York. Clean-up Measures Reconnaissance Study - Scoping

MTR NOT PROCESSED IN MAIL ROOM

Dear Study Participant:

Onondaga Lake and its tributaries have been greatly impacted by both domestic and industrial wastes that accompanied the development of the Syracuse area since the late 1800's. Reference attached Figures 1 through 3. The U.S. Army Corps of Engineers, Buffalo District is currently conducting a reconnaissance level investigation of potential clean-up measures for the lake. A general list of Federal and non-Federal alternatives currently being evaluated are attached as Figure 4.

Implementation of the National Environmental Policy Act of 1969, as amended, requires that Federal agencies initiate "an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to the proposed action." As a part of this early "scoping" process, I wish to invite your participation in this study.

In order to identify any significant resources within the project vicinity and to assess potential impacts resulting from a potential project, I am requesting that you provide your input, comments, and recommendations pertaining to this study and your interests and/or jurisdiction. Responses to this letter need not be extensive and previous coordination, if any, may be referenced but need not be reiterated. I would appreciate receiving your response within 45 days of the date of this letter.

Environmental Analysis Section
SUBJECT: Onondaga Lake, Onondaga County, New York. Clean-up Measures Reconnaissance Study - Scoping

My point of contact pertaining to this matter is Mr. Tod Smith of my Environmental Analysis Section, who can be contacted by calling 716-879-4173 (FTS 292-4173), or by writing to his attention at the above address.

Sincerely,

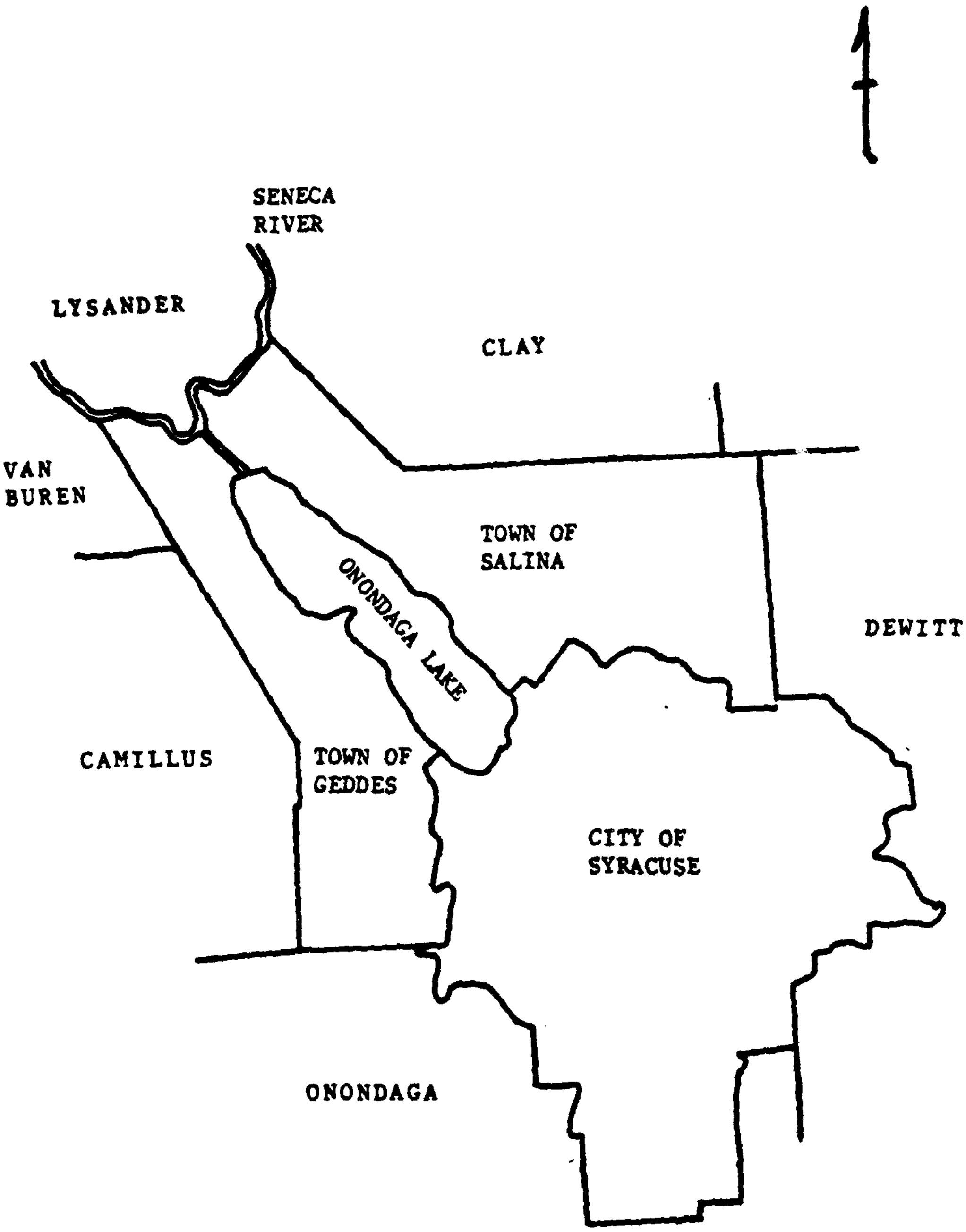
Charles C. Gilbert
fr George B. Brooks, P.E.
Chief, Engineering & Planning Division

Attachments

NOTE: The five counties that comprise New York City are frequently referred to by their borough names:
- Bronx
- Brooklyn
- Manhattan
- Queens
- Staten Island

Source: New York State Statistical Yearbook.

FIGURE 1



SCALE
1" = 2 Miles

FIGURE 2

SOURCE: Onondaga County Highway Map

ONONDAGA LAKE - SYRACUSE, N.Y.

U.S.A.C.O.E. BUFFALO, N.Y.

12

FIGURE 3

ONONDAGA LAKE - SYRACUSE, N.Y.

U.S.A.C.O.E. BUFFALO, N.Y.

11/7/90

Alternatives Under Review

Onondaga Lake, New York
Reconnaissance Study

A. Federal Alternative Plans

- o Dredging of Onondaga Lake
- o Confined Disposal Facilities
- o Solidification of Contaminated Sediments
- o Capping of Contaminated Sediments
- o In-lake Treatment
    - Aeration of the Hypolimnion
    - Chemical Treatment
- o Non-point Sources
    - Onondaga Creek Settling Basin

B. Non-Federal Alternative Plans

- o Metro Sewage Treatment Plant
    - Pump Station Upgrading and/or Expansion
    - Phosphorus Removal
    - Ammonia Removal
    - Nitrogen Removal
    - Effluent Discharge Alternative
- o Combined Sewer Overflow (CSO) Treatment and or Diversion
    - Separation of Combined Sewer Systems
    - Storage Options Alternatives
    - Regionalized CSO Collection and Treatment Facilities
    - Best Management Practices
- o Centralized CSO Transmission and Treatment Facilities
    - High Rate Treatment Facilities
    - In-water Contaminant Structures (Flow Balance Method)
    - In-line Tunnel Storage

FIGURE 4

This letter was sent to the following:

Mr. Bruce Blanchard
Director
Office of Environmental Project Review
U.S. Department of the Interior
18th and C Streets, NW - MS-4239-MIB
Washington, DC 20240

Ms. Joyce M. Wood
Director
Office of Ecology and Conservation
ATTN: Laurie Gibbons
National Oceanic and Atmospheric Administration
Department of Commerce, Room 6121 (PP/EC)
14th and Constitution Avenue, NW
Washington, DC 20230

Mr. Frank Petrone
Regional Director
Federal Emergency Management Administration
Regional Office
26 Federal Plaza
New York, New York 10278

Mr. Joseph Monticiollo
Administrator
U.S. Department of Housing and
Urban Development - Region II
26 Federal Plaza
New York, New York 10278

Mr. Robert Hargrove
Chief, Environmental Impacts Branch
U.S. Environmental Protection Agency
Region II
26 Federal Plaza, Room 702
New York, New York 10278

✓ Mr. Leonard Corin (Separate Letter)
Field supervisor
U.S. Department of the Interior
Fish and Wildlife Service
100 Grange Place, Room 202
Cortland, New York 13045

✓ Mr. William Kirshbaum
Regional Director - Region 7
New York State Department of
Environmental Conservation
615 Erie Boulevard
Syracuse, New York 13024-2400

Ms. Julia S. Stokes
Deputy Commissioner for
Historic Preservation
New York State Office of Parks,
Recreation, and Historic Preservation
Agency Building 1
Empire State Plaza
Albany, New York 12238

Mr. Richard Simberg, P.E.
Regional Director - Region 3
New York State Department of
Transportation
333 East Washington Street
Syracuse, New York 13202

Mr. Gary G. Hayes
Executive Director
Central New York Regional
Planning and Development Board
90 Presidential Plaza, Suite 122
Syracuse, New York 13202

Director
Syracuse - Onondaga County
Planning Agency
1100 Civic Center
421 Montgomery Street
Syracuse, New York 13202

Onondaga County
District Conservationist
Soil and Water Conservation District
4876 Onondaga Road
Syracuse, New York 13215

Chairperson
Onondaga County
Environmental Management Council
1100 Civic Center
421 Montgomery Street
Syracuse, New York 13202

COMMISSIONER
ONONDAGA COUNTY DEPARTMENT OF
DRAINAGE AND SANITATION
650 HIAWATHA BLVD., WEST
SYRACUSE , NEW YORK 13204-1194

Commissioner
Onondaga County
Department of Parks and Recreation
P.O. Box 146
Liverpool, New York 13088

Mr. Robert D. Hennigan
Chairman
Onondaga Lake Advisory Committee
c/o SUNY-ESF
320 Bray Hall
Syracuse, New York 13210

Commissioner, Syracuse
Community Development
217 Montgomery Street
Syracuse, New York 13201

Supervisor
Town of Salina
201 School Road
Salina, New York 13208

Supervisor
Town of Geddes
1000 Woods Road
Solvay, New York 13209

Mayor
Village of Solvay
Woods Road and 2nd
Solvay, New York 13209

Mayor
Village of Liverpool
Village Hall
Liverpool, New York 13088

Onondaga Lake Management Conference
ATTN: Mr. Timothy Mulvey
P.O. Box 7136
Syracuse, New York 13261

Mr. Lawrence Brown
Significant Habitat Unit
Wildlife Resources Center
New York State Department of
  Environmental Conservation
700 Troy - Schenectady Road
Latham, New York 12110

TOWN OF GEDDES

1000 WOODS ROAD, SOLVAY 13209
ONONDAGA COUNTY, N.Y.

SUPERVISOR
Manuel M. Martinez

COUNCILMEN
Joseph A. Longo
John F. Gosson
Joseph Rudy
Alan J. Ciciarelli
Thomas F. Sakowski
James A. Corbett

TOWN CLERK
Frances A. Marino

RECEIVER OF TAXES
Helen L. Osterhout

SUPT OF HIGHWAYS
V. Nunzio Susco

ATTORNEY
John E. Ferris

COMPTROLLER
Alfred R. Chemotti

RECREATION DIRECTOR
Cynthia R. Maggiore

November 15, 1990

George B. Brooks, P.E.
Chief, Engineering & Planning Division
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207-3199

Dear Mr. Brooks: Re: Onondaga Lake Clean-Up

Your Agency should review the LCP Plant site in the Village of Solvay.

It has been alleged that this facility has contributed significant amounts of mercury to the Lake. E.P.A's progress relative to this file has been slow. This matter must be pursued with alacrity.

The Metro Plant and the mixing of storm and sanitary flow must receive your immediate attention.

Very truly yours,

John E. Ferris

John E. Ferris
Town Atorney

JEF/mec

cc: Town Board

"Home of the New York State Fair"

TOWN OF SALINA

201 School Road
Liverpool, New York 13088
(315) 457-~~2779~~ 6661

CAROL C. BOEHLERT
Supervisor

November 20, 1990

Mr. Tod Smith
Environmental Analysis Section
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207

Dear Mr. Smith:

In reference to a letter received from George Brooks, I am enclosing some of the goals and issues discussed at the Onondaga Lake Master Development planning session on October 5, 1990.

As a member of this committee, I am most interested in the outcome of these issues as they are vital to the Town of Salina.

Thank you for your future cooperation with your project. If I may be of further assistance, please feel free to contact me.

Sincerely,

Carol C Boehlert

Carol C. Boehlert

Appendix III

Onondaga Lake Critical Issues

Environmental

1. Need for future sewage treatment facilities
2. Protection of views, vistas, natural and historic resources
3. Water surface activity and small craft use
4. EPA water quality timetable
5. State and Federal wetlands regulation
6. Potential umbrella agency
7. Knowledge of watershed, "toxic-shed", storm water, sewage, soils, habitat, non-point sources, mercury, tar beds
8. Geddes-area issues: State Fair expansion, poor economic situation, visual quality of new uses
9. Pressure on polluters, regulatory compliance
10. Northwest edge as "natural" area - protection of bird habitat
11. Use potential on waste beds

Transportation

1. Shoreline accessibility/parking (current east side) - connecting Erie Canal under Route 690
2. Area traffic planning
   - using parking for park use only
   - Conrail facilities limit development (role of railroad transportation)
3. Railroad station in regional market area
4. Alternate modes of accessibility - Village from Lake
   - Village of Liverpool serves as overflow parking for Lake activities
   - linkage needed between various nodes
5. Compatible multiple use of stadium parking

Land Use Control/Administration

1. How far back will we protect the Lake?
2. Existing and proposed industrial uses
3. Politics of saving existing downtown vs. new downtown on Lake
4. Increase in lakefront use to enhance amount and type of business (east shore)
5. Alternatives for accessing Village from Lake
6. Concerns for Geddes
   - is the State Fair liable to expand
   - how do we remove impediments to expansion
   - poor economic situation
7. Condominium development in Solvay to help tax base
8. Development of Geddes adjacent land to make it more visually pleasing
9. Potentially in conflict to Lake development goals (give priority to these issues)
10. Compatible multiple use of parking around stadium
11. Northwest side remains as natural area
12. Crucible development
13. Water sports testing center on north end for training Olympic athletes

Recreation

1. Water surface activity - public access, tour boats, water taxis
2. Professional ball stadium included in planning issues
3. Many opportunities for recreation accessed by bike
4. Vista - passive recreation
5. Erie Canal lock for recreational purposes
6. Northwest side of Lake - swimming, power skating, ice seat skating (Seal's Rock - San Francisco, Sydney Rock - Vancouver)
7. Natural area, bird area - needs to be protected
8. Harbor development and Liverpool Marina should complement each other rather than compete
9. Seasonal uses
10. Water sports testing center on north end for training Olympic athletes

Organizational Framework Issues

1. Impact on State and Federal institutions that have their own agenda - coordination needed
2. Negative public perception about Lake
   - they believe that development is possible, but are skeptical
   - negative media - "sewer"
   - Onondaga Lake Park is a favorite of the community
3. How to use this planning activity to coordinate various disparate activities
4. How to develop an implementable plan (not so much "pie in the sky" that is not achievable)
5. Where do we direct efforts - tourism vs. industrial - relative to attracting money
6. Public/private marriage to fund
   - will tax money be there for recreational development
   - imaginative plans to get around state/federal regulations/restrictions
7. Need for Onondaga Lake Commission and Shoreline Park Commission to create funding mechanisms

MAILROOM
CENCB-IM-S *Office of the Mayor*

PHONE 468-1679

17 DEC 90 10 27

WILLIAM L. CAMPAGNONI
MAYOR

VILLAGE OF SOLVAY
1100 WOODS ROAD
SOLVAY, NEW YORK 13209

December 7, 1990

Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207-3199

Attention: Mr. Tod Smith
Environmental Analysis Section

Dear Mr. Smith:

Re: Onondaga Lake, Onondaga County, New York
<u>Clean-up Measures Reconnaissance Study-Scoping</u>

This letter is in response to Mr. George B. Brooks' letter of November 13, 1990, requesting any comments on the above subject.

There are one or two points which, I believe, should be addressed pertaining to Onondaga Lake as follows:

1. During a severe rainstorm last summer, six million gallons of raw sewage was literally "dumped" into the Lake because of Onondaga County's sewage waste plant. There should be an immediate solution to this particular problem to avoid any future occurrences of this nature. The Lake is polluted enough without the addition of this type of pollutant, which probably could have been avoided had proper control been implemented.

2. The west side of Onondaga Lake, which encompasses our vicinity, should be cleaned up to at least compare with the east side of the Lake. I am certain that with some of the debris cleaned out, which has been made to accumulate over a period of time, would ensure a 100% improvement to the environment, as well as making it pleasing to the eye.

I hope the above will be of benefit in the U.S. Army Corps of Engineers' investigation of potential clean-up measures for the Lake. We all sincerely hope the day will eventually come when this clean-up will become a reality, as this is a beautiful Lake and we should do everything we can to help restore it to what it once was.

23

Very truly yours,

William L. Campagnoni

William L. Campagnoni
Mayor
Village of Solvay

WLC/pjd

Izaak Walton League of America, Inc.
NEW YORK STATE DIVISION, INC

LES MONOSTORY, SEC'Y
125 EUCLID DRIVE
FAYETTEVILLE, N.Y. 13066

December 10, 1990

Tod Smith, P.E.
Environmental Analysis Section
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207-3199

Dear Mr. Smith:

At a recent meeting of the Onondaga Lake Management Conference's Technical Liaison Subcommittee, the members reviewed the outline of federal alternative plans and non-federal alternative plans described under "Alternatives Under Review" in the scoping document for the Onondaga Lake Reconnaissance Study. The Subcommittee members expressed concern that not enough biological components were listed under the reclamation proposals, and also made a suggestion for adding another alternative for treatment of combined sewer overflows (CSO's).

In order to fully evaluate the range of remedial alternatives for lake remediation, the Corps of Engineers should review the list of alternatives described in the Proceedings of the Onondaga Lake Remediation Conference. This Conference was held at the Sagamore Conference Center in February, 1990, and was cosponsored by the N.Y.S. Department of Law and the N.Y.S. Department of Environmental Conservation. Copies may be ordered from Scott Saroff at the New York State Office of Attorney General, or from Timothy Mulvey at the Onondaga Lake Management Conference office in Syracuse.

The remedial alternatives listed in the Conference Proceedings include:
5.1 Remedial Alternatives for Contaminated Sediments
5.2 Remedial Alternatives for Water Column
5.3 Remedial Alternatives for Littoral Zone; and
5.4 Remedial Alternatives for Ninemile Creek.
The pros and cons associated with each of the remedial measures are also described. In addition to the list above, the Corps may also need to examine remedial alternatives for Onondaga Creek.

With regard to the treatment of combined sewer overflows, the Technical Liaison Subcommittee proposed an alternative treatment that has apparently not been considered to date by the County of Onondaga or the N.Y.S. Department of Environmental Conservation. The proposed alternative for CSO treatment is to use the system of wetlands located between Onondaga Lake and I-690 (along the west shore of the lake) as part of an on-site treatment system if the County of Onondaga decides to pipe the CSO's to the Seneca River. This could provide a relatively low-cost system for obtaining biological treatment of the CSO's prior to discharge into the Seneca River.

Thank you for the opportunity to comment on your scoping document, and we hope that our recommendations will assist the Corps of Engineers in its study of remedial alternatives for Onondaga Lake and its major tributaries.

Very truly yours,

Les Monostory

Les Monostory, Chairman
Technical Liaison Subcommittee
OLMC Citizens Advisory Committee

cc: George B. Brooks, P.E.
Chief, Engineering & Planning Services
Buffalo District, Corps of Engineers

Timothy P. Mulvey, Executive Director
Onondaga Lake Management Conference

ONONDAGA COUNTY
WATER QUALITY
MANAGEMENT AGENCY
CREATED BY THE ONONDAGA COUNTY LEGISLATURE

December 11, 1990

Mr. Tod Smith
Environmental Analysis Section
U.S. Army Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, New York 14207-3199

Dear Mr. Smith:

The following is in response to Mr. George Brooks' letter requesting input, comments, and recommendations pertaining to the U.S. Army Corps of Engineers reconnaissance level investigation of potential clean-up measures for Onondaga Lake.

As the communication, coordination, and advisory entity for water resource issues of concern to Onondaga County government, the Onondaga County Water Quality Management Agency (WQMA) requests that it be kept informed as to the progress of this investigation and receive any future requests for project comment or input.

The WQMA strongly feels that the remediation of Onondaga Lake warrants federal involvement. Onondaga Lake impacts the quality of the Seneca/Oswego River system and ultimately Lake Ontario, which is subject to international Water quality standards. Federal involvement is further justified by the fact that both Onondaga Lake and the Seneca/Oswego River system must meet federally mandated water quality standards. Furthermore, Onondaga Lake is a navigable waterway by federal definition.

The Agency appreciates the opportunity to comment on this study.

Sincerely,

Robert D. Hennigan

Robert D. Hennigan, Chairman
Onondaga County Water Quality Management Agency

1100 CIVIC CENTER 421 MONTGOMERY ST. SYRACUSE, N.Y. 13202 (315) 425-2616

ONONDAGA COUNTY
ENVIRONMENTAL MANAGEMENT COUNCIL

December 12, 1990

24 DEC 90 09 22
MAILROOM
CENCB-IM-S

George B. Brooks
Chief, Engineering & Planning Division
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207-3199

Dear Mr. Brooks:

I am writing on behalf of the Onondaga County Environmental Management Council (EMC) in response to your request for input on the Onondaga Lake Clean-up Measures Reconnaissance Study - Scoping. The EMC is a citizen advisory board to county government, and in this role has had extensive involvement with issues surrounding Onondaga Lake.

The EMC feels that federal involvement in the Onondaga Lake reclamation effort is well justified. In addition to the regional and geographic significance of the lake historically, recreationally and economically, there are clear national and international ramifications due to the lake's measurable impact on Lake Ontario and its surrounding communities.

Regarding the "Alternatives Under Review" outline provided with your letter, the EMC offers the following:

1) The EMC views the Army Corps of Engineers' involvement as a major plus, and looks forward to your contributions to the reclamation effort. At the same time, we view the Corps as a part of a larger effort. It is our hope that the Corps will participate in the comprehensive effort on a cooperative basis, and not view itself as a separate entity undertaking a separate and distinct action. To this end, we recommend that the Corps establish a Syracuse office to facilitate communication and coordination with all of the entities which have come together for this worthwhile endeavor.

2) It is not clear to us what the Corps used as a basis for generating this list of alternatives when the Onondaga Lake Management Conference is scheduled to fund a "Diagnostic Study" in 1991. We feel it is possible that the Diagnostic Study might reveal additional needs, therefore the need to consider additional alternatives.

3) The EMC feels strongly that the Corp's prioritized list of alternatives needs to be reorganized. It is our sense that the "In-Lake Treatment" alternative is the most practical and promising at this time. This, coupled with our serious concern over the potential negative impacts the dredging alternative might have, compels us to recommend that the In-Lake Treatment alternative be placed at the top of the list, and the dredging alternative at the bottom, if not removed entirely.

4) Regarding the "Non-Point Sources" alternative, it is our understanding that this is in response to the "mudboil" issue. The EMC feels strongly that this alternative must encompass urban drainage or urban nonpoint pollution as well. Whether related to this area of concern or not, the EMC also feels that lake managers must be prepared to address contaminated groundwater discharges to the lake, and that such a possibility should be reflected in whatever alternatives are finally given consideration.

5) Regarding "Non-Federal Alternative Plans", it is our position that these alternatives merit consideration as part of the Federal Alternative Plans insomuch as they comprise a major and inseparable piece of the reclamation effort. There appears to be a major federal focus on the clean-up of mercury contaminants and sediments originating from mudboils, both of which are known or believed to be caused by certain industrial dischargers. We feel that federal involvement must also focus on the sewage treatment plant and CSOs, which impact dissolved oxygen, lake clarity, and nutrient and bacteria loading to the lake.

Thank you for the opportunity to comment on the Onondaga Lake Clean-up Measures Reconnaissance Study - Scoping. If you have any questions or would like us to clarify any of our recommendations, please contact David Coburn, EMC Executive Director, at (315) 435-2640. It is anticipated that the EMC will be asked to comment on the results of the diagnostic study to be completed in 1991, and that we will be better able to assess remediation alternatives at that time.

Respectfully,

David W. Stoner
Chairman

New York State Office of Parks, Recreation and Historic Preservation
The Governor Nelson A. Rockefeller Empire State Plaza
Agency Building 1, Albany, New York 12238-0001

Orin Lehman
Commissioner

December 12, 1990

Mr. George B. Brooks, P.E.
Chief, Engineering & Planning Division
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207-3199

Dear Mr. Brooks:

Re: CORPS
Proposed Clean-up Measures for
Onondaga Lake
Geddes, Onondaga County
90PR2464

Thank you for requesting the comments of the State Historic Preservation Office (SHPO). We have begun to review the project in accordance with Section 106 of the National Historic Preservation Act of 1966 and the relevant implementing regulations.

Based upon our review, it is the SHPO's opinion that the Onondaga lake area is known to contain numerous prehistoric and historic archeological sites. We recommend that the reconnaissance survey include a thorough assessment of the project areas history and land use, including both land based and submerged archeological site potential. Actual survey requirements will be greatly influenced by proposed impacts and their locations. Pertinent archeological file sources which probably should be consulted are our office, the New York State Museum (contact Ms. Beth Wellman at 518-474-5813) and the State University of New York at Binghamton, Public Archeology Facility (contact Dr. Nina Versaggi at 607-777-4786). These contacts, in turn may know of other sources of information.

In addition, if any physical or visual impacts are anticipated to buildings over 50 years in age then these buildings and the possible effects warrant consultation. If you have any questions, please call Edward Dudek of our Project Review Unit at (518) 474-0479.

Sincerely yours,

Julia S. Stokes
Deputy Commissioner for
Historic Preservation

17 DEC 90
MAILROOM
CENCB-IM-S

JSS/ED:tr

30

Historic Preservation Field Services Bureau • 518-474-0479
Urban Cultural Parks • 518-473-2375

An Equal Opportunity/Affirmative Action Agency

Onondaga Lake Management Conference
SUITE 541, 100 SOUTH CLINTON STREET
P.O. BOX 7136
SYRACUSE, NEW YORK 13261

TIMOTHY P. MULVEY
Executive Director

(315) 472-2150
FAX 474-0537

December 14, 1990

George B. Brooks, P.E.
Chief, Engineering & Planning Division
U.S. Army Corps of Engineers
1776 Niagara Street
Buffalo, NY 14207-3199

Re: Reconnaissance Study - Scoping Inquiry

Dear Mr. Brooks:

I have advised the members of the Onondaga Lake Management Conference of your inquiry dated November 13, 1990.

As you may be aware, Col. John Morris, Commander of the Army Corps of Engineers for the Buffalo District, is a member of the Onondaga Lake Management Conference. In addition, this office has worked closely with David McPherson, Project Coordinator of the Corps' Reconnaissance Study, in developing information and alternatives concerning Onondaga Lake as part of the Corps' Reconnaissance Study.

Accordingly, I believe that your office is fully apprised of the role of the Management Conference in developing a comprehensive Management Plan for the cleanup of Onondaga Lake. Should you require any further details or assistance from this office, please feel free to contact me.

Very truly yours,

Timothy P. Mulvey

Timothy P. Mulvey

TPM/sl
cc: David McPherson

CENCB-PE-PR

DEC 17 1990

SUBJECT: Onondaga Lake, New York Reconnaissance Study - Coordination with the U. S. Fish and Wildlife

Mr. Leonard Corin
Supervisor
U. S. Fish and Wildlife Service
ATTN: Thomas McCartney
Fish and Wildlife Biologist
100 Grange Place, Room 202
Cortland, New York 13045

17 DEC 90 14 55
MAILROOM
CENCB-IM-S

Dear Mr. Corin:

As per a recent telephone conversation between Mr. Thomas McCartney and Mr. Leonard Bryniarski on December 5, 1990, I am forwarding copies of three maps outlining approximate locations of alternative confined disposal sites presently under consideration in the Onondaga Lake, New York, Reconnaissance Study that is presently being conducted by the Buffalo District. Also, included are three additional maps that outline approximate areas in the lake containing mercury in the bottom sediments that have concentrations equal to or greater than 1, 5 and 10 parts per million.

The aforementioned maps, along with narrative information on the alternative plans previously mailed to your office, should be of use in preparation of the Planning Aid Letter that is due at the Buffalo Corps District office by December 18, 1990.

My point of contact pertaining to this matter is Mr. Leonard Bryniarski, of my Environmental Analysis Section, who can be contacted at commercial number (716)879-4173 or FTS 292-4173 or by writing to his attention at the above address.

Sincerely,

George B. Brooks P.E.
George Brooks, P.E.
Chief, Engineering & Planning Division

ONONDAGA LAKE ADVISORY COMMITTEE
DEDICATED TO THE REVITALIZATION OF ONONDAGA LAKE AND RELATED LAND AREAS

7 JAN 91 09 25

January 3, 1991

Mr. Tod Smith
Environmental Analysis Section
US Department of Defense
Department of the Army
Buffalo District, Corps of Engineers
1776 Niagara Street
Buffalo, New York 14207-3199

Subject: Onondaga Lake, Onondaga County, New York
Clean-up Measures Reconnaissance Study-Scoping

Dear Mr. Smith:

Enclosed is a listing of action required for Onondaga Lake rehabilitation that was included in my testimony to Congress. This covers the items I think are necessary if we are to reach the goals of swimmable and fishable as well as continued economic development, increased recreational use and meeting the aesthetic demands related to the above uses.

A number of items deserve inclusion in this project or related projects:

1. Remediation of the mud boils in Onondaga Creek Valley by:

   a) reducing artesian water pressure,
   b) providing treatment for mud boil overflow.

2. Rehabilitation of Onondaga Creek by:

   a) clearing and snagging,
   b) dredging,
   c) rerouting stream,
   d) providing temporary storage for both rural and urban run-off,
   e) altering operating regimen of dam in valley.

3. Rehabilitation of Nine Mile Creek by:

   a) dredging,
   b) rerouting stream (lower section by waste beds),
   c) sealing stream bottom,
   d) intercepting waste bed run-off and providing treatment

Robert D. Hennigan, Chairman 320 Bray Hall, SUNY-ESF, Syracuse, N.Y. 13210, 470-6636
Susan Miller, Exec. Secty., NYS - DEC, 615 Erie Blvd., Syracuse, N.Y. 13204, 426-7400

Mr. Tod Smith
January 3, 1991
Page Two

4. Onondaga Lake

   a) Rehabilitation of littoral zone in whole or in part by dredging and replacement with sand and gravel.
   b) Dredging of lake bottom in areas of maximum accumulation, e.g., delta-nine mile creek.

Consideration of the above would be appreciated.

Sincerely,

Robert D. Hennigan, Chairman
Onondaga Lake Advisory Committee

RDH:djr

APPENDIX "A"

ACTIONS NECESSARY FOR RECLAMATION AND REHABILITATION OF ONONDAGA LAKE

I. MANAGEMENT AGENCY

1. Create a management agency to direct and oversee the program.

II. COMBINED SEWERS

2. Evaluate alternatives to capture and treat combined sewer overflows on Ley Creek, Onondaga Creek and Harbor Brook.
3. Institute remedial action to abate combined sewer overflows. This work must be closely coordinated with the redesign and redevelopment of Onondaga Creek.

III. POINT INPUTS

4. Evaluate the effluent requirements and compliance of the metropolitan treatment plant and for other point sources discharging to the lake and tributaries

IV. MODELING STUDIES

5. Complete the modeling studies and development of appropriate model(s) for the following elements:

   a. phosphorous
   b. nitrogen
   c. bacteria
   d. dissolved oxygen
   e. algal blooms
   f. transparency
   g. sediment generation, transport and impact

V. IN-LAKE OXYGEN TRANSFER

6. Evaluate the cost and technical feasibility of providing for in lake aeration to increase oxygen levels in the hypolimnion during periods of stratification .

VII. GROUNDWATER

7. Conduct a hydrogeologic study of the tributary land areas from the St. Marie area ground the southern end of the Lake to the northern extremities of the Allied waste beds including those areas between Route 370 and the Lake on the east side, the area between Route 690 and Lake on the south side and southwest side, the Allied-Signal site, and the area between the Lake the waste beds. The purpose of this study is to determine the nature and extend of groundwater flow into the Lake .

VII. REMEDIAL ACTION INDUSTRIAL RESIDUALS

8. Prepare a remedial action and implementation plan for the Willis Avenue site of Allied Signal.

9. Prepare a remedial action and implementation plan for the benzene lagoons of Allied Signal.

10. Prepare a remedial action and implementation plan for the Allied-Signal waste beds.

11. Prepare a remedial action and implementation plan for the mercury deposits in the Lake due to Allied-Signal and LCP inputs.

VIII. MUD BOILS

12. Analyze the impact of the clay particles and sediment originating from the mud boils in Onondaga Creek Valley on Onondaga Creek and on Onondaga Lake .

IX. LAKE SEDIMENT DEPOSITS

13. Determine the extend and nature of the sediment deposits in the Lake from natural origins and from cultural activities.

14. Evaluate the feasibility of dredging Lake sediment deposits from the littoral zone and from the deeper lake areas to improve aesthetics and recreational uses, create or improve fishery habitats and/or to remove pollutants.

X. ONONDAGA CREEK

15. Carry out a comprehensive study on the feasibility of the rehabilitation and redesign of Onondaga Creek with the following objectives:

a. Maintainence of minimum flows to support a viable fishery and to allow passage for Atlantic Salmon in the spring and fall months.

b. Control of high flows through off stream storage retention basins within the city of Syracuse as well as better use of the existing flood control dam south of the city.

c. Redesign of thethe creek cross-section to reduce high flow velocities in order to minimize the existing hazard due to a narrow deep channel with steep concrete walls making it a serious safety hazard.

d. Rerouting of the creek to create a more aesthetically pleasing and more useful and less dangerous urban waterway.

e. Creation of an urban amenity with real recreational, aesthetic and commercial benefits to the local community.

XI. NINEMILE CREEK

16. Determine the best method to rehabilitate the lower section of Ninemile Creek from the mouth to the end of the Allied-Signal waste beds.

17. Devise a remedial action plan to rehabilitate Ninemile Creek.

XII. LEY CREEK AND HARBOR BROOK

18. Determine the most effective way to improve Ley Creek and Harbor Brook for their best social economic use.

XIII. SALMON RUN

19. Determine action necessary to establish a salmon run from Lake Ontario up the Oswego River up the Seneca River through Onondaga Lake and up Onondaga Creek and/or Ninemile Creek for spawning purposes.

XIV. LAND USE AND ECONOMIC DEVELOPMENT

20. Prepare an economic development plan on a short and long term basis. Such plan to incorporate parkland development around Lake, redevelopment of the Allied-Signal site, Oil City, Franklin Square, Regional Market and any other lands impacting on the Lake area.

XV. NON-POINT INPUTS

21. Prepare an analysis and evaluation of non-point inputs and impacts on the Lake, and develop a plan to manage such inputs.

XVI. IMPLEMENTATION

22. Prepare specific implementation plans and actions to carry out all needed work. These to include a financial plan which allocates cost between public and private sources and between the Federal, State and Local Governments. Evaluate existing institutions to determine ability to carry out the program, if indicated new institutions should be created to carry out the program. Develop a financial plan designed to guarantee completion of the needed work.

23. Assign each task to the appropriate Federal agency, State agency and Local agency.

24. Provide for financing of each of the tasks.

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
333 EAST WASHINGTON STREET
SYRACUSE, N.Y. 13202

RICHARD SIMBERG
REGIONAL DIRECTOR

FRANKLIN E. WHITE
COMMISSIONER

11 Jan 91 10

January 4, 1991

Mr. George B. Brooks, P. E.
U.S. Department of Army
1776 Niagara Street
Buffalo, New York 14207-3199

RE: Onondaga Lake, Onondaga Co., Clean-Up Measures Reconnaissance Study - Scoping

Dear Mr. Brooks:

The NYS Canal System currently has a maintenance facility based at the Syracuse Canal Terminal located on Onondaga Creek at the southeastern end of Onondaga Lake. We have responsibility to maintain the lake level for navigation purposes and maintain navigation channels to and from the lake.

Our areas of concern in the clean-up measures reconnaissance study is the Canal channel in Onondaga Creek and the adjacent Canal owned property. The Onondaga Creek entrance to the lake is subject to siltation and requires periodic dredging. The sediment comes naturally from the creek and from overflows of the Syracuse combined storm and sanitary sewer system. The sediment is dredged and placed upland in disposal adjacent to the Canal. We have had problems in recent years in obtaining permits to dredge the sediments because of contaminents.

Another issue is the future of the Canal lands in the Syracuse terminal. The City of Syracuse has plans to redevelop this harbor area into a commercial and recreational land use. The suitability of materials dredged from Onondaga Lake for these alternate uses is unknown.

We recommend that the sediments in the Canal channel and previously dredged sediments be included in the reconnaissance study. They should be investigated to determine the degree of clean-up needed for the upland property and a methodology developed for determining future dredging needs.

The Department has a legal interest in the lake and appreciates the opportunity to be a participant in the study.

Sincerely,

RICHARD SIMBERG, P. E.
Regional Director
Region 3

cc: J. Jermano, Waterways Maintenance Division, 216-5
J. Baldwin, Regional Waterways Maintenance, Region 3
T. Ryan, Office of Communications, 524, 5
D. Geoffroy, Office of Operations, 503-5

11/07

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II
26 FEDERAL PLAZA
NEW YORK NEW YORK 10278

FEB 06 1991

Mr. George B. Brooks, P.E.
Chief, Engineering and Planning Division
U.S. Army Corps of Engineers
Buffalo District
1776 Niagara Street
Buffalo, New York 14207-3199

Dear Mr. Brooks:

The Environmental Protection Agency (EPA) has reviewed the scoping document for a reconnaissance level investigation of potential clean-up measures for Onondaga Lake, Onondaga County, New York. It is our understanding that the project proposed by the U.S. Army Corps of Engineers (USACE) and the multi-lateral efforts being initiated by the Onondaga Lake Management Conference (OLMC) are closely related. In fact, the USACE reconnaissance study may serve as the first step towards achieving the OLMC goals.

As you are aware, we are involved with the activities underway to determine the problems that exist in the lake and its watershed, and the activities underway to develop and implement restoration techniques through our efforts as a member of the OLMC. In addition to the issues we have raised through the OLMC, and the information provided in the scoping document, we recommend that the reconnaissance study include a delineation of all potentially impacted wetlands according to the three parameter federal method. Additionally, we recommend the performance of an ecological assessment of the area. This assessment should include inventories of macroinvertebrates, fishery resources, avians, and mammals that utilize the area for nesting and foraging.

Thank you for the opportunity to comment. We would appreciate your sending us five copies of the reconnaissance study when it is complete. Should you have any questions, please contact Mr. John Filippelli, Chief, Federal Activities Section at (212) 264-6723.

Sincerely yours,

Robert W. Hargrove

Robert W. Hargrove, Chief
Environmental Impacts Branch

ANNEX D

Onondaga Lake
New York

Bibliography

Bibliography

Allied-Signal Inc.	Allied-Signal, Inc.Involvement with Onondaga Lake, 1989
	Waste Bed Feasibility Study Sec. 1-4, Feb. 1990
Allied-Signal, Blasland & Bouck Engineers	
Allied-Signal, Blasland & Bouck Engineers	Hydrogeologic Assessment of the Allied Waste Beds in the Syracuse Area, Vol. 1, 1989
Allied-Signal, Inc., Blasland & Bouck Engineers	Waste Bed Feasibility Study, Sections 5 & 6, April 1990
Andrews, R.	A Lake Grown Old Before its Time, Post-Standard, Oct. 1985, newspaper article
Auer, M.T.	Monitoring Fecal Coliform Bacteria in Onondaga Lake and its Tributaries-1987, 1989, Upstate Freshwater Institute
Auer, M.T., Brooks, C.M.	Determination of Nitrogen Kinetics in Laboratory Microcosms, 1988, Upstate Freshwater Institute, 21 p.
Auer, M.T., Johnson, N.A.	Phosphorus Release from Onondaga Lake Sediments, 1989, Upstate Freshwater Institute, 29 p.
Auer, M.T., Niehaus, S.L.	Fecal Coliform Bacteria Kinetics in Onondaga Lake, NY, 1989, UpstateFreshwater Institute, 49 p.
Auer, M.T., Storey, M.L.	Growth Kinetics of Onondaga Lake Phytoplankton, 1989, Upstate Freshwater Institute, 50 p.

Auer, M.T., Storey, M.L., Effler, S.W., Auer, N.A. — Zooplankton Impacts on Chlorophyll and Transparency in Onondaga Lake, New York, USA, 1988, Upstate Freshwater Institute, 31 p.

Barton & Loguidice, PC — Liverpool Pump Station Facilities Plan C-36-1200-05, June 1987, Addendum

Blasland & Bouck Engineers, PC — Ley Creek Service Area Improvements Facilities Planning Study C-36-1200-06; June 1987; Addendum #2 to Draft EIS

Blasland & Bouck Engineers, PC — Ley Creek Service Area Improvements Facilities Planning Study, C-36-1200-06, June 1987, Addendum #1 to Draft EIS

Blasland & Bouck Engineers, PC — Ley Creek Service Area Improvements Facilities Planning Study, May 1987, Draft EIS

Blasland & Bouck Engineers, PC — Ley Creek Service Area Improvements Facilities Planning Study C-36-1200-06, June 1987, Main Report, Vol 2 of 2

Blasland & Bouck Engineers, PC — Ley Creek Service Area Improvements Facilities Planning Study, C-36-1200-06, June 1987, Main Report, Vol. 1 of 2

Bloom, N.S., and Effler, S.W. — Seasonal Variability in the Mercury Speciation of Onondaga Lake, New York, UFI, 1990

Bloom, Nicolas — A Preliminary Mass Balance for Mercury in Onondaga Lake, New York, February 1990

Brooks, C.M., Effler, S.W.	The Distribution of Selected Nitrogen Species in Onondaga Lake, New York, 1989, Upstate Freshwater Institute, 124 p.
Calocerinos & Spina	Onondaga Lake Monitoring Program 1984, November 1985
Calocerinos & Spina	Onondaga Lake Monitoring Program 1982, November 1983
Calocerinos & Spina	Facilities Plan for In-Water Combined Sewer Overflow Abatement Study, August 1983
Calocerinos & Spina	Onondaga Lake Monitoring Program 1981, Dec 1982 107 Calocerinos & Spina Onondaga Lake Monitoring Program 1983, Dec 1984
Calocerinos & Spina	Revised Landfill Closure Plan, Vol. 1, January 1986, Crucible Specialty Metals
Calocerinos & Spina	Revised Landfill Closure Plan, Volume 2, Appendices, Figures, Drawings, January 1986, Crucible Specialty Metals
Calocerinos & Spina	Geotechnical Investigations, App. A&B, Vol. 3 of 4, May 1982, Crucible Inc. Solid Waste Management Facility
Canale, R., Effler, S.	Stochastic Phosphorus Model for Onondaga Lake, Wat. Res., Vol. 23, No. 8, p. 1009-1016, 1989

Central New York Regional Planning and Development Board Onondaga Lake	Water Quality Management Project-FY88, 1989, DEC and USEPA funded
Central New York Regional Planning and Development Board	Onondaga Lake and Watershed Management Project, Final Report, March 1986
Chapra S., Canale R.	Long-term Phenomenological Model of Phosphorus and Oxygen for Stratified Lakes, 20 p. Water Research, 1990
Clarke, John M.	The Squids from Onondaga Lake, NY, Science, p. 947-948, 1902
Devan, S., Effler, S.	History of Phosphorus Loading to Onondaga Lake, Journal of Environ. Engineering, Vol. 110, No. 1, Feb. 84, p. 93-109
Dionne, Jean-Claude	Miniature Mud Volcanoes and Other Injection Features in Tidal Flats, James Bay, Quebec; Can. J. Earth Sci. Vol. 13, 1976; p. 422-428
Drehwing, F.J., Oliver, A.J., MacArthur, D.A., Moffa, P.E., O'Brien & Gere	Disinfection/Treatment of Combined Sewer Overflows, August 1979, USEPA
Effler S.,	Address J.Methane Cycling in Onondaga Lake, NY, UFI, Dec 1990, 112 p.
Effler, S.	Secchi Disc Transparency and Turbidity, Journal of Environmental Engineering, Vol. 114, No. 6, Dec. 1988, p. 1436-1447

Effler, S., Wodka, M., Driscoll, C., Brooks, C., Perkins, M., Owens,E.	Entrainment-Based Flux of Phosphorus in Onondaga Lake, Journal of Environmental Engineering, Vol. 112, No. 3, June 1986, p. 617-622
Effler, S., Wodka, M., Field, S.	Scattering and Absorption of Light in Onondaga Lake, Environmental Engineering, Vol. 110, No. 6, Dec. 1984, p. 1134-1145
Effler, S.W.	Onondaga Lake Can This Lake be Saved, 1990, Clearwaters, Vol.19, No. 4, pg.14-16
Effler, S.W.	The Impact of a Chlor-Alkali Plant on Onondaga Lake and Adjoining Systems, Water, Air and Soil Pollution, 1986
Effler, S.W.	Hypereutrophy and Pollution in Onondaga Lake, N.Y.,American Water Resources Association, UFI May 1987
Effler, S.W., Brooks, C.M., Auer, M.T., Doerr, S.M.	Free Ammonia and Toxicity Criteria in a Polluted Urban Lake, 1990
Effler, S.W., Driscoll, C.T.	Calcium Chemistry and Deposition in Ionically Enriched Onondaga Lake New York, 1985, Envir. Sci Technol,V.19.P.716-720
Effler, S.W., Driscoll, C.T., Wodka, M.C., Honstein, R., Devan, S.P.Jaran, P., Edwards, T.	Phosphorus Cycling in Ionically Polluted Onondaga Lake, NY, Water, Air, and Soil Pollution, 1985
Effler, S.W., Field, S.D., Meyer, M.A. and Sze,P.	Response of Onondaga Lake to Restoration Efforts, 1981, Jour. of Env Eng Div.,V.107,P.191-210

Effler, S.W., Hassett, J.P., Auer, M.T., Johnson, N.	Depletion of Epilimnetic Oxygen and Accumulation of Hydrogen Sulfide in the Hypolimnion of Onondaga Lake, NY, Water, Air, Soil Poll. 1987
Effler, S.W., Jaren, P.,Carter, C.F.	Onondaga Lake and Dissolved Oxygen in Seneca River, UFI, Journal of Envir. Engr, 1982
Effler, S.W., Johnson, D.L., Jiao, J.F., Perkins, M.G.	Optical Impacts and Sources of Tripton in Onondaga Creek, USA, Upstate Freshwater Institute, 1989
Effler, S.W., Owens, E.M.	Modifications in Phosphorus Loading to Onondaga Lake, USA, Associated with Alkali Manufacturing, 1987, p. 177-182
Effler, S.W., Owens, E.M.	Changes in Stratification in Onondaga Lake, NY, Water Resources Bulletin, Upstate Freshwater Inst., 1989
Effler, S.W., Owens,E.M. Schimel, K.A.	Density Stratification in Ionically Enriched Onondaga Lake, USA, Upstate Freshwater Inst. No.42, 1986
Effler, S.W., Perkins, M.G.	Failure of Spring Turnover in Onondaga Lake, N.Y. USA, No.42, 1987
Effler, S.W., Schimel, K., Millero, F.J. Salinity,	Chloride, and Density Relationships in Ion Enriched Onondaga Lake, NY, UFI, No.40, 1986
Effler, S.W.,Devan, S.P., Rodgers, P.W.	Chloride Loading to Lake Ontario From Onondaga Lake, NY UFI 1985

Effler, S.W.,Doerr, S.M., Brooks, C.M., Rowell, H.C.	Chloride in the Pore Water and Water Column of Onondaga Lake, NY, UFI 1985
Effler, S.W.,Driscoll, C.T.	A Chloride Budget for Onondaga Lake, New York, USA, UFI,No.38, 1986
Effler, S.W.,McCarthy, J.M., Simpson, K.W., Unangst, F.J., Schfran, G.C., Schecher, W.D.	Chemical Stratification in the Seneca/Oswego Rivers, NY. UFI No.10, 1984
Effler, S.W.,Owens, E.M.	The Density of Inflows to Onondaga Lake USA 1980 & 1981, Upstate Freshwater Institute, No.44, 1986
Effler, S.W.,Perkins, M.G.,Brooks, C.	The Oxygen Resources of the Hypolimnion of Ionically Enriched Onondaga Lake, NY, USA, UFI No. 62, 1987
Effler,S.W., Rand,M.C., and Tamayo,T.A.	The Effect of Heavy Metals and Other Pollutants on the Sediments of Onondaga Lake, 1979,Water,Air and Soil Poll, V.12, P.117-134
Effler. S.W., Perkins, M.G. Field, S.D.	Onondaga Lake and the Dynamics of Chloride in the Oswego River, UFI NO 24, 1984
Field, S., and Effler, S.	Temperature and the Productivity-Light Relationship, Water Resources Bulletin, Vol. 24, No. 2, April 1988, p. 325-328
Field, S.D.	Nutrient-Saturated Algal Growth in Hypereutrophic Onondaga Lake, Syracuse, NY, Dec. 1980, UMI

Field, S.D., Effler, S.W.	Light Attenuation in Onondaga Lake, NY, USA, 1978, Upstate Freshwater Institute, #9, November 1983
Field, S.D., Effler, S.W.	Light-Productivity Modal for Onondaga Lake, NY, UFI Journal of Envir Engr., 1983
Field, S.D., Effler, S.W.	Photosynthesis-Light Mathematical Formulations, Journal of Envir Engr. UFI, 1982
Flocke, L.	Cleaning Up the State's Most Polluted Lake, NYSDEC, Water Bulletin, 1990, Region 7
Flocke, L.	Cleaning Up the State's Most Polluted Lake, Region 7, NYSDEC Water Bulletin, August 1990
Freedman, P.L., Canale, R.P., Pendergast, J.F.	Modeling Storm Overflow Impacts on Eutrophic Lake, Journal of Environmental Engineering Division, p. 335-349, 1980
Gambrell, R.P., Patrick, W.H.	The Influence of Redox Potential on the Environ. Chemistry of Contaminants in Soils & Sediments, Ecol. & Management of Wetlands, 1984
Garofalo, J., Effler, S.	Coating of Zooplankton with Calcium in Onondaga Lake, New York, Environ. Sci. Technol., Vol. 21, No. 6, 1987, p. 604-606
Gelda, R., Auer M., Effler S., Chapra S., Storey M.	Determination of Reaeration Coefficients: A Whole Lake Approach, UFI, 1990
Getchell, F.A.	Subsidence in the Tully Valley, NY, Nov 1982

Harman, W.N., Berg, C.O. | Freshwater Mollusca of the Finger Lakes Region of NY, 1970

Harold, C. | The Green Lakes of Onondaga, Dec. 1855, p. 618-623

Harshadeep, N.R. | Geographic Information Systems as a Tool for Hydrologic Modeling; Application to the Onondaga Creek Watershed, Aug 1990, Thesis

Heidtke, T.M. | Onondaga Lake Loading Analysis: Total Phosphorus, 1989, Upstate Freshwater Institute, 124 p.

Heidtke, T.M. | Onondaga Lake Loading Analysis: Fecal Coliforms, 1989, Upstate Freshwater Institute

Hennigan, R.D. | America's Dirtiest Lake, 1989, Clearwaters, Vol.19, No.4, pg.8-12

Higgins, G.L. | Saline Groundwater at Syracuse, NY, July 1955

Holland, J.P., Tate, C.H. | Investigation and Discussion of Techniques for Hypolimnion Aeration/Oxygenation. U.S. Army Waterways Experiment Station, October 1984, Final

Johnson, D.L. | Individual Particle Analysis and Transparency in Onondaga Lake-1987,1989, Upstate Freshwater Institute, 21 p.

Kennedy, R.H., Cooke, G.D. | Control of Lake Phosphorus with Alumnium Sulfate: Dose Determination and Application Techniques, Water Resources Bulletin, Vol. 18,

#3, June 1982

Kennedy, R.H., Cooke, G.D. | Precipitation and Inactivation of Phosphorus As a Lake Restoration Technique, February 1981, NTIS

Lorenzen, M., East, A. | A Guide to Aeration/Circulation Techniques for Lake Management, January 1977, NTIS

McBean, E.A., Poland, R., Rovers, F.A., Crutcher, A.J. | Leachate Collection Design for Containment Landfills, Journal of Envir. Eng. Feb 1980

Meyer, M.A., Effler, S.W. | Changes in the Zooplankton of Onondaga Lake, NY, 1969-1978, Envir.Pollution, 1980

Moffa & Assoc., Stearns & Wheler | Workplan for Onondaga Lake Study Management Alternatives, May 1990

Moffa & Associates | Onondaga Lake Monitoring Program 1986, April 1988

Moffa & Associates | Onondaga Lake Monitoring Program 1986, Appendix, April 1988

Moffa & Associates | Analysis of Pre-BMP CSO Analytical Data, Memorandum, May 1990

Moffa & Associates | Calibration & Validation of CSO Collection System Computer Models for Main & Harbor Broad Interceptors Using CSO Data, Memo, Feb. 1990

Moffa & Associates | Overflow Monitoring & BMP Evaluation, Memoranda, Feb 88

Moffa & Associates	Combined Sewer Overflow Facilities Plan Update, Report, Dept. of Drainage & Sanitation, September 1990
Moffa & Associates	Combined Sewer Overflow Facilities Plan Update, Appendix, Department of Drainage & Sanitation, September 1990
Moffa & Associates; Stearns & Wheler	Workplan for Onondaga Lake Study Management Alternatives, 1989, 21p.
Moffa, P.E.	The Seeds of Pollution, 1987, Technologist, Vol.1, No.2, pg.8-9
Moffa, P.E., Deguida, R.N., Geldof, N., Ott, R.	Water Quality Impacts from Combined Sewer Overflow and Non-Point Source Discharges and Resulting Abatement Strategies, 1990
Moffa, Peter E.	Onondaga Lake...The Future, May 1987, Technologist, 2 p.
Moffa, Peter E.	When Will We Swim in Onondaga Lake? Early History, No. 1 of 4, Feb. 1987, Technologist, 2 p.
Moffa, Peter E.	Pollution Abatement for Onondaga Lake, No. 3 of 4, April 1987, Technologist, 3 p.
Muller, E.	Surficial Geology of the Syracuse Field Area, p. 25-35, 1964
NYS Department of Environmental Conservation	Application for Permit to Discharge for Syracuse, Onondaga County, 1988

NYS Department of Environmental Conservation	Engineering Investigations at Inactive Hazardous Waste Sites, Phase II, Vol. 1, Site No. 734030, 1989
NYS Department of Environmental Conservation	Engineering Investigations at Inactive Hazardous Waste Sites, Phase II, Vol. 2, Site No. 734030, 1989
NYS Department of Environmental Conservation	Engineering Investigations at Inactive Hazardous Waste Sites, Phase II, Vol 2 (cont'd), Site 734030, 1987
NYSDEC	Oswego River Remedial Action Plan, Stage I, February 1990
NYSDEC	1989 New York Nonpoint Assessment Statewide Summary, June 1990
NYSDEC	1989 New York Nonpoint Assessment Report for Onondaga County, June 1990
NYSDEC	Oswego River Remedial Action Plan, Stage II Preliminary Report, Oct. 29, 1990
NYSDEC	Report on the Water Quality Study of Onondaga Lake, May-Sep 75
Niehaus, S.L., Auer, M.T.	Application of the Onondaga Lake Fecal Coliform Model to Predict Total Coliform Concentrations, 1989, Upstate Freshwater, 16 p.

O'Brien & Gere — The Onondaga Lake Drainage Basin, Oswego River Drainage Basin Survey Series, Report No. 1, 1951

O'Brien & Gere — Combined Sewer Overflow Abatement Program, Metropolitan Syracuse Treatment Plant Service Area, June 1979

O'Brien & Gere — Combined Sewer Overflow Abatement Program Post BMP Assessment, Nov 87, Final

O'Brien & Gere Consulting Engineers — Onondaga Lake Study 1968-69, part of report, 460 p.
4 Onondaga County Onondaga Lake Study, 1971,

Environmental Protection Agency, Water Quality Office, — Water Pollution Con Research Series, 487 p.

Owens, E.M. — A Model of Transport of Fecal Coliform Bacteria in Onondaga Lake, New York, 1989, Upstate Freshwater Institute, 80 p.

Robel, R., Briggs, J., Dayton, A, and Hulbert, L. — Relationships Between Visual Obstruction Measurements and Weight of Grassland Vegetation, Technical Notes, p. 295-297, 1969

Rowell, H. Chandler — Sediment Data From Onondaga Lake, SUNY, 1990

149 Shilts, W.W. Nature and Genesis of Mudbiols, central Keewatin, Canada, February 1978, Can. J. Earth Sci. Vol. 15

Sloan, R. — Trends in Mercury Contamination of the fish in Onondaga Lake, NYSDEC, 1990

Sloan, R.J., Skinner, L.C., Horn, E.G., Karcher, R.	An Overview of Mercury Contamination in the Fish of Onondaga Lake, July 1987, NYSDEC
Smardon, R., Drake, B., Kalinoski, R.	Oil City Remediation Workshop, Final Report, Vol. 1, Sep. 89.
Sonzogni, W., Richardson, P., Monteith, T.	Chloride Pollution of the Great Lakes, Journal WPCF, Vol. 55, No. 5,p. 513-521, 1983
Spagnoli, J., Skinner, L.	PCB's in fish from Selected Waters of New York State, Vol. 11, No. 2 Sept. 1977, Pesticides Monitoring Journal, p. 69-87
Stearns & Wheler	Onondaga Lake Monitoring Program Annual Report-1987, 1989, Department of Drainage & Sanitation
Stearns & Wheler	Onondaga Lake Monitoring Program Annual Report 1987, App. B, February 1989
Stearns & Wheler	Comprehensive Performance Evaluation for Metropolitan Syracuse Sewage Treatment Plant, Final Report, May 1989
Stearns & Wheler	Onondaga Lake Monitoring Program 1980, August 1981
Stearns & Wheler	Onondaga Lake Storms Impact Study, August 1979
Stearns & Wheler	Onondaga Lake Monitoring Program 1988, April 1990

Stearns & Wheler	Onondaga Lake Monitoring Program 1988, April 1990, App. B
Stearns & Wheler	Onondaga Lake Monitoring Program 1989, Tables & Graphs, April 1990
Stearns & Wheler	Methodology for Evaluating the Impact & Abatement of Combined Sewer Overflows, Nov 80
Stearns & Wheler	Current Metro Syracuse STP Performance Characteristics, Task Report No. 1, July 1990
Stearns & Wheler	Performance Characteristics Phosphorus Removal Alternatives, Task Report No. 3, September 1990
Stearns & Wheler	Performance Characteristics Ammonia Removal Alternatives, Metro Syracuse STP, Onondaga County, NY, Task Report No. 5, 1990
Stearns & Wheler	Ley Creek STP Reconstruction, Task Report No. 4, Memorandum, Sep 1990
Stearns & Wheler	Extraneous Flow Abatement, Metro Syracuse STP, Task Report No. 2, July 1990, Memorandum
Stearns & Wheler	Effluent Discharge Alternatives Metro Syracuse STP, Task Report No. 8, Nov. 5, 1990
Stearns & Wheler	Performance Characteristics Nitrogen Removal Alternatives, Task Report No. 6, October 1990

Syracuse-Onondaga County Planning Agency County	Growth & Infrastructure, Onondaga County Plan Report 1, 2010 Development Guide, 1990
Sze, P.	Possible Effect of lower phosphorus concentrations on the phytoplankton in Onondaga Lake, NY, USA
Sze, P.	The Phytoplankton of Onondaga Lake, NY, Thesis, May 1972, UMI
Sze, P., Kingsbury, J.M.	Distribution of Phytoplankton in a Polluted Saline Lake, Onondaga, NY, 1971
Terzaghi, R.D.	Brinefield Subsidence at Windsor, Ontario, Harvard University
UFI	Various Chemical Analysis, 1988
UFI	Bathymetric Survey and Mapping of Onondaga Lake, NY, April 88
USDA Soil Conservation Service	Preproposal for the Development of a Comprehensive Assessment of Nonpoint Source Pollution and Management Plan of Corrective Actions, July 1990
USEPA	Onondaga Lake Diagnostic-Feasibility Phase I; Clean Water Act, Section 314 Grant Proposal, 1989, 82 p.
USEPA	EIS on the Wastewater Treatment Facilities Construction Grants for the Onondaga Lake Drainage Basin, Final, May 1974

United States District Court	State of New York and Thomas C. Jorling vs. Allied-Signal and Department of Sanitation, 1989
Webster, Dwight A.	Temperatures And Related Factors in Lakes, Part I, The Conservationist, June-July 1970
Weiner, Mark	The Water Onondaga Creek: A stream awash in trash, April 1990, Syracuse Herald Journal
Wilcox, D., Effler, S.	Formation of Alewife Concretions in Polluted Onondaga Lake, Environ.Pollution, 1981, p. 203-215
Winkley, S.J.	The Hydrogeology of Onondaga County, NY, May 1989
Wodka, M., Effler, S., Driscoll, C.	Phosphorus deposition from the epilimnion of Onondaga Lake, Limnol. Oceanogr., 1985, p. 833-843
Wodka, M.C.,Effler, S.W., Driscoll. C.T., Field, S.D., Devan, S.P.	Diffusivity-Based Flux of Phosphorus in Ondondaga Lake, Upstate Freshwater Institute, Journal of Envir. Engrg. Vol. 109, #6, 1983
Yin, C., Johnson, D.L.	An Individual Particle Analysis and Particle Analysis Budget Study of Onondaga Lake Sediments, UFI, No. 19, 1984
Young, T.C., DePinto, J.V., Seger, E.S.	Transport and Fate of Heavy Metals in Onondaga Lake, New York, Bull.Environm. Contam. Toxicol. 29, 554-561 (1982)